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TECHNICAL REPORT RD-AC-93-1

TACTICAL UNMANNED GROUND VEHICLE RELATED RESEARCH REFERENCES (BTA STUDY)

Virginia Young
Larry Brantley
Advanced Systems Concepts Office
Research, Development, and Engineering Center

MARCH 1993

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898-5000

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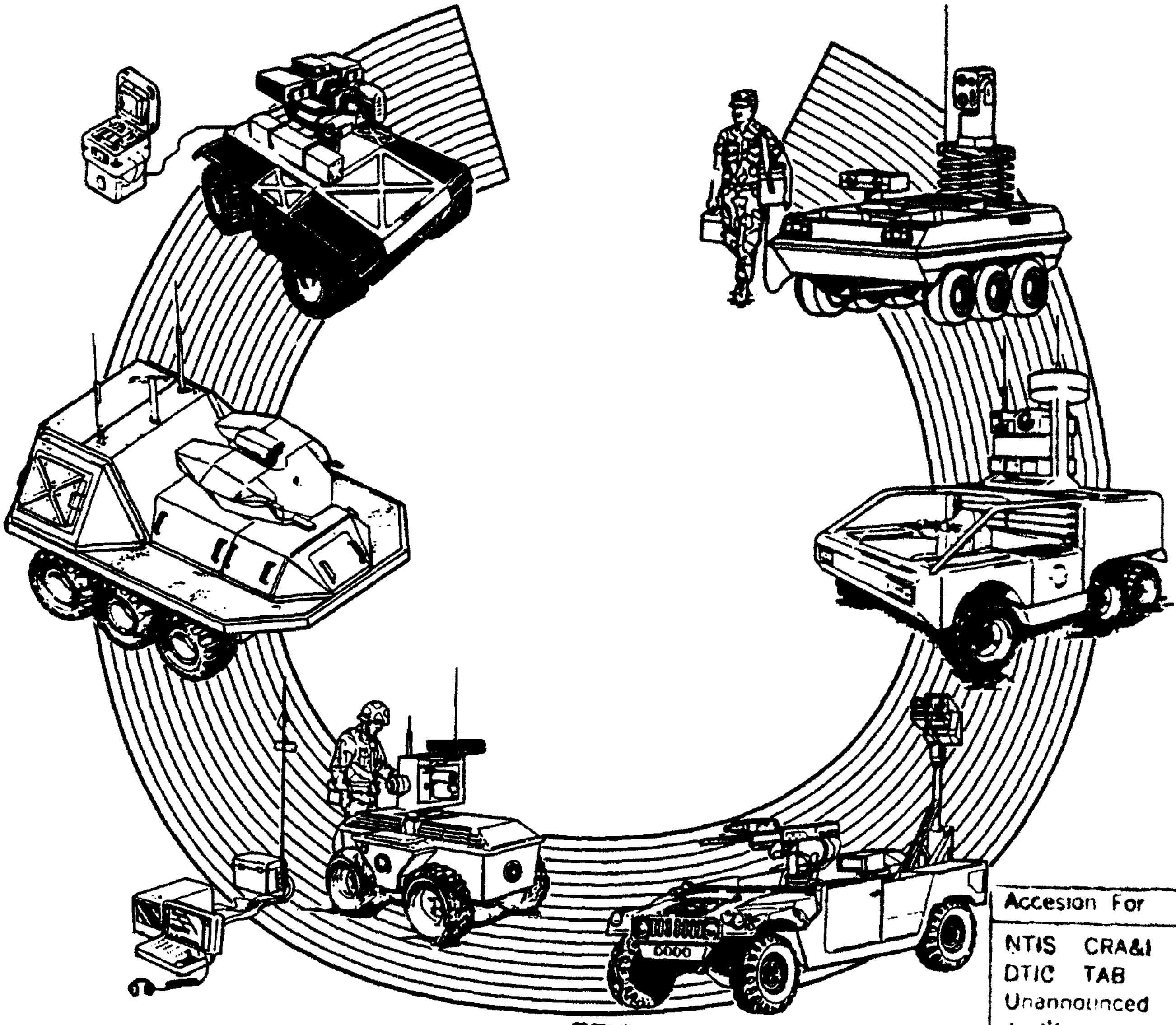

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Virginia Young
Larry Brantley

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Commander
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ATTN: AMSMI-RD-AC-AD
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13. ABSTRACT *(Maximum 200 words)*

This report is an effort to review available literature related to Unmanned Ground Systems and supporting technology for the purpose of assisting the development of hardware solutions to requirements for an unmanned ground system. This manageable set of references details pertinent references with summaries and catalogues references relative to component support.

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LIST OF ACRONYMS

AA	Abbreviated Analysis
AMC	U.S. Army Materiel Command
AROD	Airborne Remotely Operated Device
ASAP	Army Streamlined Acquisition Process
ATA	Automatic Target Acquisition
ATR	Automatic Target Recognition
ATV	All-Terrain Vehicle
BCC	Battlefield Circulation Control
BOT	Burst-On-Target
BTA	Best Technical Approach
CALEB	Tactical Unmanned Ground Vehicle
CARD	Computer Aided Remote Driving
CCD	Charged Coupled Device
CECOM	Computer and Electronics Command
CFP	Concept Formulation Package
COE	Concept Of Employment
COEA	Cost and Operational Effectiveness Analysis
COEE	Concept of Employment Evaluation
COM ECM	Communication Electronic Countermeasures
COM ESM	Communication Electronic Support Measures
CS	Control Station
CV	Control Van
DARPA	Defense Advanced Research Projects Agency
DCT	Discrete Cosine Transform
DGPS	Differential Global Positioning System
DPCM/VLC	Differential PCM coding and Variable Length Coding
DSTI	Dynamic System Technologies Incorporated
ECM	Electronic Counter-Measures
EMP	Electromagnetic Pulse
EMI	Electromagnetic Interference
EOM	Countermeasures
FEC	Forward Error Correction
FELICS	Feedback Limited Control System
FLIR	Forward Looking Infra-red

LIST OF ACRONYMS (cont.)

FO	Fiber Optic
FOV	Field-of-View
GATORS	Ground Air Teleoperated Robotic System
GFE	Government Furnished Equipment
GPS	Global Positioning System
HEL	U.S. Army Human Engineering Laboratory
HFOV	Horizontal Field-Of-View
HMD	Head Mounted Display
HMMWV	High-Mobility Multi-Wheeled Vehicle
IBSSU	Internal Bearing Stabilized Sighting Unit
IFF	Identify Friend or Foe
IR	Infrared
IR&D	Independent Research and Development
IRLS	Infra-Red Linescanner
IRST	Infra-Red Search and Track
ISOR	Marine Corps Initial Statement of Requirement
LADAR	Laser Direction and Ranging
LLLTV	Low Light Level Television
LOS	Line Of Sight
MAD	Magnetic Anomaly Detector
MAPS	Modular Azimuth Positioning System
MBU	Mobile Base Unit
MDARS	Mobile Detection Assessment Response System
MET	Meteorological
MICOM	U.S. Army Missile Command
MILES	Multiple Laser Engagement System
MP	Mobile Platform
MTI	Moving Target Indicator
MULE	Modular Universal Laser Equipment
NBC	Nuclear, Biological, and Chemical
NCCOSC	Naval Command and Control Ocean System Center
NDI	Non-Developmental Items
NIST	National Institute of Standards and Technology
NLOS	Non Line Of Sight

LIST OF ACRONYMS (cont.)

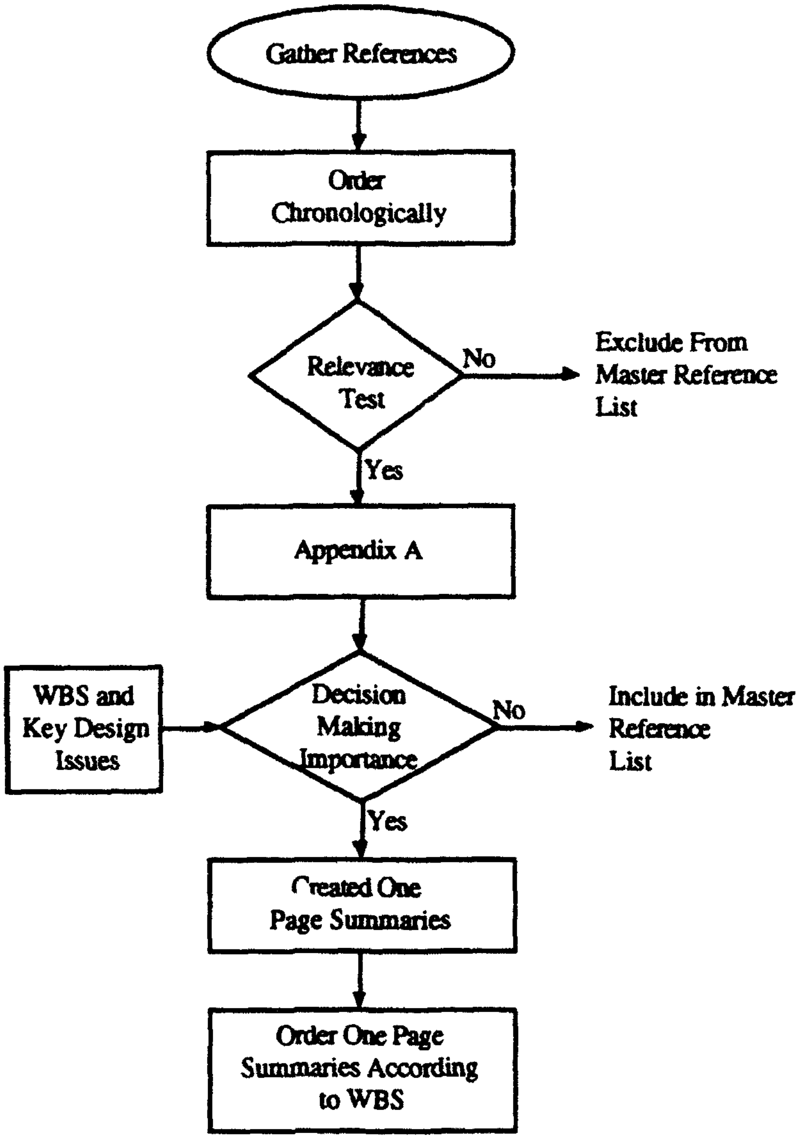
NONCOM ECM	Non-Communication Electronic Countermeasures
NONCOM ESM	Non-Communication Electronic Support Measures
NOSC	Naval Ocean Systems Center
OCS	Operator Control Station
OCU	Operator Control Unit
O&O Plan	Operational and Organizational Plan
ORD	Operational Requirements Document
P3I	Preplanned Product Improvements
PIPE	Pipelined Image Processing Engine
PRECOM	Predictive Coding Using the Cosine Transform and Motion Compensation
PROWLER	Robotic vehicle
RABFAC	Radar Beacon Forward Air Controller
RANGER	Robotic vehicle
RAW	Rifleman's Assault Weapon
RCS	Real-Time Control System
RDTE	Research, Development, Test and Evaluation
RF	Radio Frequency
RISTA	Reconnaissance, Intelligence, Surveillance, and Target Acquisition
ROC	Required Operational Capability
RV	Remote Vehicle
SAR	Synthetic Aperture Radar
SINCGARS	Single Channel
SMMP	System Manprint Management Plan
SOP	Standard Operating Procedures
SPIKE	Hypervelocity kinetic energy penetrating rocket
SSG	Special Study Group
SSV	Surrogate Semiautonomous Vehicle
STF	Special Task Force
STV	Surrogate Teleoperated Vehicle
TIRs	Technical Incident Reports
TMAP	Teleoperated Mobile Anti-Armor Project
TNS	Terrain Navigation System
TOA	Trade-Off Analysis
TOD	Trade-Off Determination

LIST OF ACRONYMS (cont.)

TOE	Theories of Employment
TOV	Teleoperated Vehicle
TRADOC	U.S. Army Training and Doctrine Command
TS	Transport Subsystem
TUGV	Tactical Unmanned Ground Vehicle
TV	Television
UGV	Unmanned Ground Vehicle
UGVJPO	Unmanned Ground Vehicle Joint Project Office
UHF	Ultra-High Frequency
USAIS	U.S. Army Infantry School
USMCCDC	U.S. Marine Corps Combat Development Command
UTM	Universal Transverse Mercator
VFOV	Vertical Field-Of-View
VHF	Very-High Frequency
VIPER	RAW
VNAS	Vehicle Navigation Aid System
VQ	Vector Quantization

1.0 INTRODUCTION

This report was prepared in an effort to review the available literature related to Unmanned Ground Vehicle (UGV) development for the purpose of assisting on the generation of a Best Technical Approach (BTA). The approach taken for this effort was broken into the seven-step procedure shown in the following figure:



Step One involved gathering various reports, papers, and other written documents which were related to UGV issues. Step Two was the organization of these papers into chronological order. Step Three was accomplished by reviewing all available references for applicability to the current UGV design effort (i.e. operational requirements, design approaches, and test results). Step Four was the generation of a Master Reference List which included all references which passed through the screening process of Step Three. In Step Five, references were specifically reviewed for applicability to key design issues and major/minor UGV subsystems (MBU, OCU, Datalink, Payloads,

etc.) found in the Work Breakdown Structure (WBS). Step Six involved a final in-depth review and a one page summary of all references which were applicable to key design issues or major/minor UGV subsystems. In Step Seven, these summaries were organized chronologically and according to the WBS. The summaries provide valuable insight into various aspects of UGV systems and provide a foundation for recommendations which appear in the final BTA. These summaries have been included in this report.

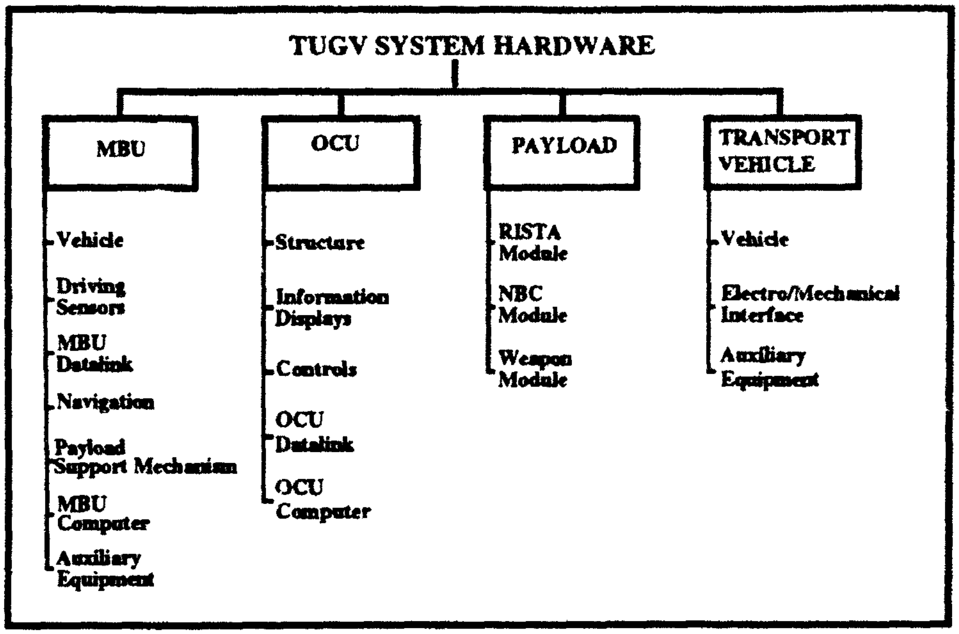
Step One involved accessing the AMSMI-RD-AC-AD Advanced System Concept Office's database located at Redstone Arsenal, Alabama. This database included over 1000 test reports and various other types of reports from such sources as Naval Command and Control Ocean Systems Center (NCCOSC-formally NOSC), U.S. Army Human Engineering Laboratory (HEL), Harry Diamond Laboratory (HDL), Tank Automotive Command (TACOM), Computer and Electronics Command (CECOM), Sandia National Laboratory (SNL), Oak Ridge National Laboratory (ORNL), Unmanned Ground Vehicle Joint Project Office (UGV-JPO), Unmanned Aerial Vehicle Joint Project Office (UGV-JPO), and U.S. Army Missile Command (MICOM). These reports ranged from the 1960's to the present.

In Step Two, all references were organized by year, month, and day to aid in determining which references were applicable to the current UGV design effort. The rationale behind this being that the more recent papers/documents were thought to be more applicable to the current UGV design effort. Furthermore, this type of organization allowed a chronological look at the progress of UGV systems.

Step Three was an effort to identify all available references which discussed operational requirements, design approaches, and/or test results. Operational requirement documents which were reviewed during the literature search include: 1) the Army Operational and Organizational (O&O) Plan; 2) the Marine Corps Initial Statement of Requirements (ISOR); 3) Operational Mode Summaries; and 4) the Army Operational Requirements Document (ORD). The following are examples of design approaches found during the literature review: 1) camera placement techniques; 2) camera aiming options; 3) supervisory driving algorithms; and 4) data compression algorithms. Additional references which were reviewed contained test results from the following types of tests: 1) stereoscopic vision versus monoscopic vision; 2) color displays versus monochrome displays; 3) fixed camera versus steering-slaved cameras; 4) field-of-view (FOV); 5) peripheral vision; and 6) datalink compression techniques.

In Step Four, all of the documents which passed through the screening process described in Step Three were included in the chronological UGV master reference list found in the back of this report as Appendix A. The current master reference list contains 1,134 references.

In order to be of value, the list of references must be reduced to a more manageable set which contains only those significant few which provide evidence which supports choices among alternatives for the BTA. To accomplish this, the UGV system was decomposed into four major subsystems which were further decomposed into minor subsystems (found in the work breakdown structure) as shown in the following figure:



Step Five was an effort to identify all available references which discussed key design issues and major/minor UGV subsystems. An example of these key design issues is shown in the following figure:

EXAMPLE KEY DESIGN ISSUES		
MBU	Supervisory Driving	Field-Of-View (FOV)
	Vehicle Speed	Peripheral FOV
	Stereo	Steering Slaved Cameras
	Color	Camera Placement
Payload	Stereo	Weight
	Color	Weapons Capability
	Automatic Target Acquisition And Tracking	Acoustics
	Field-Of-View (FOV)	Mast Stability
	Peripheral FOV	
OCU	Helmet-Mounted Displays	Signature
	Flat Panels	Weight,
	CRTs	Fiber Optic Constraints
	Steering Controls (joystick, yoke, handlebars, etc.)	
Datalink	Data Compression	Radio Frequency (RF) Equipment Weight
	Non-Line Of Sight	Fiber Optic Weight
	Relays	Range
	Fiber Optics	Survivability

In Step Six, all references filtered through the process described in Step Five, were reviewed in depth and summarized in a one page format. These summaries highlight equipment that has been used on previous systems to meet operational/technical requirements and provide valuable information on issues such as: using color displays, using head-mounted displays, correct camera positioning, preferred camera aiming techniques, benefits of stereoscopic vision, proper field of view (both horizontal and vertical), zooming capabilities, fiber optics, weapon issues, mast issues, recognition ranges, detection ranges, identification ranges, acoustic sensor benefits, navigation units, and datalink compression techniques.

In Step Seven, these summaries were organized chronologically and according to the WBS. This was done in an effort to facilitate the use of this report as an analysis tool by the BTA Team.

MOBILE BASE UNIT (MBU)

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Common Problems in the Evaluation of 3D Displays, 1983

Author(s): John O. Merritt

OBJECTIVE:

The potential benefits of stereoscopic visual displays have often been overlooked in a number of important application areas. Commonly occurring problems in stereoscopic display evaluation are illustrated with examples from the literature.

APPROACH:

The analysis presented here is drawn from previously published research and from the author's personal experience with several 3-D display system evaluation projects. Examples from the literature are used to show how certain changes in experimental factors can drastically alter the results of the stereo evaluation.

LESSONS LEARNED:

Stereo display systems are usually thought of as aids to seeing where things are in 3-dimensional space. One very important side benefit of stereo is seeing what things are in an unfamiliar scene. Laboratory comparisons of stereo and non-stereo displays usually involve repeated trials with simple, familiar objects; thus the operationally important stereo advantage in figure-ground separation is not recognized. This "image interpretation" advantage of stereo is particularly important for remote-viewing systems that have limited resolution or poor gray scale in the visually complex scenes found in operational settings. Stereo display techniques can aid perception through separation of terrain and foliage images that are jumbled together in conventional FLIR or LLLTV (Low Light Level TV) used for nap-of-the-earth flight. In addition, just as visual performance with two eyes is better than with one, a stereo display can effectively separate uncorrelated noise from image signal in the two channels, a feat effortlessly performed by the human visual system. This effectively provides up to 40 percent better resolution with existing display technology. In addition to improving effective image quality, a two-channel stereo system, like a twin-engine aircraft, provides a single-camera contingency mode in case one channel should fail. While the doubled complexity of the stereo system raises the probability of a single camera failure, the probability of failure in both camera channels is significantly reduced.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Visual Performance and Fatigue with Stereoscopic Television Displays, 22 - 25 April 1984

Author(s): Edward H. Spain and Robert E. Cole

OBJECTIVE:

To present the results of an experiment which tested factors relevant to the perception of depth in stereoscopically televised remote environments.

APPROACH:

A geometrical model describing retinal disparities produced by stereoscopic TV systems is briefly discussed and experimentally tested for various configurations of camera separation and magnification. Operator visual fatigue induced by these configurations is also measured. Although geometrical configurations do affect perceptual performance, they do not affect it in a manner consistent with the simple geometrical model.

LESSONS LEARNED:

Camera separation exerted an influence on both verbal and haptic measures of perceived depth but did not do so in a manner consistent with the simple geometrical model of retinal disparities. When disparities increased beyond "normal" levels as a result of increasing camera separation, perception of depth in the remote environment became more accurate, not more distorted. Magnification was not found to have a significant influence on perceived depth. Targets used in this experiment were unpatterned, and so a major benefit of magnification, that of increased detail resolution, could not have been a significant factor in determining depth perception. Measures of visual efficiency taken before and after testing with the stereo TV system failed to show any statistically significant differences in visual fatigue across the set of values for camera separation and magnification tested. It should be noted, however, that great care was taken in balancing and aligning the two channels of the TV system and that average testing time on the stereo display was only about 20 minutes. Thus, moderate exposure to "unnatural" disparities produced by a carefully tuned stereo TV system do not appear to engender very much if any visual fatigue in observers.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Stereoscopic and Volumetric 3-D Displays: Survey of Technology, June 1984

Author(s): T. E. Phillips

OBJECTIVE:

To investigate available stereoscopic and volumetric (ie, nonperspective) three-dimensional (3-D) display technologies, report on the current state-of-the-art, and select candidate technologies that have near-term applicability to command and control display needs.

APPROACH:

Three-dimensional display can conveniently be broken down into three categories: 1) perspective 3-D, 2) stereoscopic 3-D, and 3) volumetric 3-D. This report will address the latter two techniques: stereoscopic and volumetric 3-D display. Emphasis has been placed on assessment of methods that can be applied to the presentation of dynamic NTDS graphics and symbology. Since the techniques under consideration present cues to depth that are not commonly used in computer graphics, a section describing the mechanisms of depth perception is included.

LESSONS LEARNED:

Of the available techniques, only stereoscopic display appears to hold promise for near-term application to command and control needs. Varifocal mirror techniques have potential for console-type displays where ambient lighting and display volume are not crucial considerations. All other methods, such as holography, lenticular screens, and scanning slit parallax barriers, require extensive research and/or development efforts. A major obstacle to rapid utilization is the general lack of personal experience with 3-D display in those who have the best perception of where it might be applied, coupled with the difficulty of portraying the effect of 3-D displays in hardcopy form.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Stereographics Stereoscopic Video System Results From Testing Indoors, 26 February 1986

Author(s): U.S. Army Engineer Topographic Laboratories

OBJECTIVE:

The USAETL Topograhic Developments Laboratory has in-house a three dimensional stereoscopic video system consisting of two video cameras with matched lenses, a display controller, a camera controller, viewing glasses, and a 19" video monitor. A VCR is interfaced with the system to record the video image. This video camera system display will deliver a flickerless, full-color image to one or more users. The Automated Compilation Branch has tested and evaluated the system's capabilities and documented the results in the following report.

APPROACH:

The stereoscopic video system was analyzed through the results of three separate tests conducted on the system. The three tests include: test patterns (registration pattern, resolution pattern, and gray scale); pegboard testing; and square background testing. The tests conducted with the test patterns will evaluate the operation of the stereoscopic video system, and the pegboard and square background tests will compare stereopsis to the monoscopic depth cues. The goal of the tests conducted is to determine if the 3D stereoscopic video camera system will increase the amount of information that the display user can extract from the video image.

LESSONS LEARNED:

The display indicated a compressed image at the top and stretched at the bottom. Since both cameras showed similar non-linearities, the monitor itself is probably out of adjustment. With the wide angle lenses, the number of gray levels detected does not depend on the interaxial separation of the cameras, but does depend on the lighting conditions and the distance from the camera. With the telephoto lenses, the number of gray levels detected does not depend on the interaxial separation or the lighting conditions or the distance from the camera (up to 20 '). The results of testing indicate that distance, more than interaxial separation, affects depth perception. The best results were obtained using 3D viewing with a short distance from the pegboard to the cameras and a large interaxial separation between the two cameras. The conclusion of the Square Background Test is that 3D viewing is an improvement over 2D viewing in detecting a difference in depth of objects that lack monoscopic depth cues. 3D viewing would be a valuable tool for camouflage applications, because 3D viewing would increase the ability of the observer to find camouflaged objects (objects whose color is similar to the environmental background) in an environment where 2D viewing would not detect the camouflaged object.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trade-Off Study for the Mobility Sensor: Pan-and-Tilt, Hydraulic or Electric?, 27 February 1986

Author(s): Eric K. S. Lee

OBJECTIVE:

The purpose of this study is to determine whether electrical or hydraulic power should be used to operate the mobility sensor for the GATERS ground vehicle.

APPROACH:

Criteria that affect the choice between electric and hydraulic power are examined in this study. The decision-making process used to arrive at the conclusions are described in Appendix 1. Methods of calculations are described in Appendices 2 and 3. The following criteria were used to compare the relative advantages of an electrically powered and a hydraulically powered mobility sensor: performance, commercially available units, durability, service and repair, size and weight, complexity, short term operation without engine power, power and efficiency, and cost. To compare electric and hydraulic power, typical systems had to be assumed. A PMI S6M4H servo drive motor with a 60:1 harmonic drive and PMI power amplifier were chosen to represent a typical electrical system. The drive train was assumed to be a chain and sprocket or belt and pulley. Compact Air hydraulic cylinders and Dyval Inc. servo valves were chosen to represent a typical hydraulic system. A summary of decision-making criteria is presented in Table 1.

LESSONS LEARNED:

The flexibility of hydraulics allows easy modification to produce a variety of peak torques and speeds at low cost. This flexibility makes hydraulics preferable to electronics in the category of performance. The only potentially useful commercial pan and tilt is hydraulic and costs approximately $4500. If this unit proves satisfactory during testing, it will be an overwhelming factor in favor of a hydraulic system. Under Durability, hydraulics are slightly advantageous since the performance of the electrical system is degraded at extreme temperatures and waterproof motors are expensive. In the categories of Size and Weight, Service and Repair, and Complexity, there are no significant differences between the two systems. The electrical system is clearly advantageous for short term operation without engine power since it does not require the addition of an energy storage system. Under Power and Efficiency, hydraulics are preferable due to higher efficiency and more reserve power. A cost comparison shows the hydraulic components to be less expensive that the electronic components.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Technology Assessment for Command and Control of Teleoperated Vehicles, May 1987

Author(s): Douglas E. McGovern

OBJECTIVE:

To investigate the present state of the art in vehicle command and control with emphasis on the man/machine interface.

APPROACH:

Discussion of specific functions involved in vehicle operation and human/machine associated capabilities. Discussion of system performance trade-offs and recommendations for future development.

LESSONS LEARNED:

Stereoscopic vision is important in remote manipulation tasks and close-in maneuverability. Conjectured that color will increase operator ability to identify targets and locate obstacles.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Current Development Needs in the Control of Teleoperated Vehicles, July 1987

Author(s): Douglas E. McGovern

OBJECTIVE:

To review experimental studies of remote driving to gain an understanding of the control requirements for teleoperation of land vehicles.

APPROACH:

Reviewed experimental studies and investigated the related technologies of vision, kinesthetic feedback, training, and performance measurement. Through this review, a number of significant areas requiring additional development work were identified.

LESSONS LEARNED:

The most significant reported work in land vehicle teleoperation involved comparison of the time taken to complete a marked course with a teleoperated vehicle versus the time required when manually driving the same vehicle. Vision for teleoperation was provided by a video system in which two cameras were mounted on a pan/tilt unit on board the vehicle. The drive for the pan/tilt was taken from the operator's head position. Thus, the driver turned his head to look at an area of interest, and the cameras were driven to follow. The operator's helmet was configured with video displays such that stereo vision was perceived. The results of this testing indicated at least a factor of two reduction in vehicle speed between manual (on-board) driving and remote driving. In a different application, tests were run using a small vehicle in an indoor environment. The operator was to negotiate a path through a maze, identifying the widest openings of gateways contained in the maze. The operator was more effective using a stereo video system (more accurate choice of widest opening) than with a single video presentation (two dimensional display) but, the time to complete the course was slower. With a high resolution camera (750 horizontal pixels), a 6.5 degree field-of-view (FOV) is required for presentation of normal (20/20) vision to the operator. With a FOV of about 90 degrees, the visual equivalent is worse than 20/150 (what can be seen at 20 feet is the same as seen from 150 feet away with normal vision). Stereoscopic video has been demonstrated to be of importance in close-in vehicle maneuverability. When visual cues/kinesthetic cues do not replicate actual experience, a condition commonly known as "simulator sickness" may result. Symptoms can include nausea, dizziness, spinning sensations, and confusion. It has been the experience at Sandia that it is very difficult to maintain operator awareness of vehicle tilt and roll. As a result, vehicle rollovers have occurred.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A Demonstration of Retro-Traverse Using a Semi-Autonomous Land Vehicle, April 1988

Author(s): D. E. McGovern, P. R. Klarer, and D. P. Jones

OBJECTIVE:

To demonstrate retro-traverse on a semi-autonomous land vehicle.

APPROACH:

Initial course planning, maneuver generation, and obstacle avoidance are performed through teleoperation. Vehicle returns autonomously to the start location by reversing route already traveled.

LESSONS LEARNED:

Local obstacle detection and avoidance system will be required. The dead reckoning and position control system had a small amount of error.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperation: Telepresence and Performance Assessment, April 1988

Author(s): Ross L. Pepper and Peter K. Kaomea

OBJECTIVE:

The objectives of the fundamental research in human perception and human factors engineering being pursued at NOSC is twofold: First, we seek to enhance the effectiveness of advanced teleoperator systems by improving the display of information to the operator of the system. Secondly, we are working to acquire the knowledge base needed to provide the human engineering design principles required for the next generation of teleoperator work systems and telerobotic devices.

APPROACH:

Our initial approach is to review existing human psychomotor, perceptual, and cognitive performance test batteries, as well as proposed robotic evaluation criteria, for tests/criteria to be included in the Teleoperator Performance Evaluation Battery. In addition to discrete human psychomotor performance using a teleoperator system, we are pursuing the development of a broad range of measures to assess the role of telepresence in both operator performance during manual control operations as well as during periods of system autonomy (intermittent autonomy), whereby the operator performs a monitoring function.

LESSONS LEARNED:

Stereo TV provides a significant performance advantage over conventional TV when: 1) the remote scene is unfamiliar or frequently changing, 2) the rate of learning new tasks is important, 3) errors must be avoided or minimized, 4) tasks have significant depth-positioning requirements, and 5) imagery is degraded. In previous work, the generic peg-in-hole task was not found to depend heavily on the depth positioning cues produced by the retinal disparity available in the Stereo View condition. The present study replicates these previous findings while using a much more precise taskboard design and a greatly increased range of task difficulty.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A Laboratory-Simulation Approach to the Evaluation of Vision Systems for Teleoperated Vehicles, June 1988

Author(s): D. P. Miller and D. E. McGovern

OBJECTIVE:

This experiment was conducted to compare three vision systems using actual vehicle teleoperations and videotape simulation derived from vehicle teleoperation.

APPROACH:

Three video systems were used for testing: 1) a steering-slaved color CCD camera, 2) a fixed-color CCD camera with the color turned off at the monitor, and 3) a fixed-color CCD camera displayed in color. The lens provided about forty degrees horizontal field of view (HFOV) and resolution was about 300 horizontal TV lines. Subjects detected and identified objects or obstacles on the course that were important to vehicle control. These objects included artificial objects and natural features. Two groups were tested. The driving group remotely operated the vehicle over a marked course avoiding obstacles in their path. The simulation group watched a prerecorded videotape of driving the same course and identified obstacles as they were approached.

LESSONS LEARNED:

Simulation subjects expressed a preference for a narrower HFOV, and teleoperation subjects indicated a preference for a wider HFOV with the difference being statistically significant. Performance in obstacle detection showed no significant difference among any of the experimental conditions; although a slight advantage appeared in the color condition. Investigation of individual obstacles for differences in detection range between simulation and teleoperation showed mixed results. Surprisingly, no steering-slaved advantage was seen. This may be accounted for in the fact that this was only a detection task and not an actual driving task. Color had only a nine foot detection range advantage over black and white in the obstacle detection task. The similarity of performance in the simulation and teleoperation conditions suggested that the non-interactive simulation technique can realistically measure visual performance on tasks associated with off-road vehicle teleoperation. The simulation technique here could potentially save much time and effort when used in trade studies involving various vision systems for vehicle teleoperation.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Camera Stabilization Techniques for Ground-Air Teleoperated Vehicles, November 1988

Author(s): H. M. Costello, S. M. Killough, J. C. Rowe, and W. R. Hamel

OBJECTIVE:

To investigate the feasibility of the accelerometer feedback approach to camera stabilization through computer simulation and experimental verification.

APPROACH:

The basic approach taken was TOV modeling, control algorithm design, and test stand development and implementation. First, vehicle motion was studied. Second, a control algorithm was developed to compensate for the level of disturbances transmitted to the camera from the vehicle. Third, a single-degree-of-freedom test stand was designed and fabricated to examine the stabilization control algorithm. In the final step, the control algorithm was implemented on the test stand and evaluated.

LESSONS LEARNED:

Active camera stabilization requires inertial balancing, nonobstructive mounting, and measuring and feeding back the disturbance. The prevalent method used to actively feed back the disturbance is the implementation of a gyroscope by either mechanically coupling the gyro to the camera or by driving a control system using the gyro output signal. An example of the latter approach is the internal bearing stabilized sighting unit (IBSSU) developed by McDonnell Douglas. Commercially available camera stabilization systems are widely used in aircraft and news broadcast industries. As mentioned above, gyro-based stabilization systems are the predominant type of active stabilization. Several types of units were located that use gyroscopes mechanically coupled to the camera mirror or lens. These units include the KB-29A Strike Camera System by Fairchild, the GS 915 stabilized mirror unit by British Aerospace Inc., the CAI cameras by Optical/Recon, Inc., and the news industry's Gyrozoom by Schwem Technology. The CAI and Fairchild systems are both bulky and prohibitively expensive -- in excess of $100K for some of the CAI systems. The accelerometer feedback approach tracked low frequency inputs nearly perfectly while removing as much as 75% of the camera jitter vibration. Camera jitter frequencies of 3 and 4 Hz were reduced by 90%.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Proposed Designs for Teleoperated Vehicle (TOV) Brake Improvements and Auto-Park Sequence, 1 November 1988

Author(s): C. Metz

OBJECTIVE:

The objectives of this task are to: 1) improve the "feel" of the control station brake pedal to give the operator a more realistic braking response and 2) develop a method that controls vehicle braking in response to the amount of force applied by the operator to the control station brake pedal.

APPROACH:

To provide a more realistic "feel" to the brakes it is proposed that the hydraulic cylinder, currently installed as a damper for the brake pedal spring, be capped. Air will be bled into the system until the pedal has the same range of motion as an actual HMMWV brake pedal. The use of a fluid/air "spring" on the brake pedal should produce a realistic spongy feel. To provide improved control in the braking system it is proposed that control station brake system pressure, rather pedal displacement, be used to regulate braking of the TOV. By utilizing this type of control scheme the operator should be able to prevent abrupt stopping by regulating the amount of force he applies to the pedal.

LESSONS LEARNED:

By making the control station brake pedal feel more realistic and improving the method by which vehicle brakes are controlled, an operator will be able to more accurately estimate, based on his previous driving experience, how much pedal pressure is needed to slowly or rapidly decelerates the vehicle. At present the only ways the operator can determine how the vehicle is braking in response to his actions is by visually perceiving a change in the rate at which the surrounding landscape passes by or by tilting the mobility head to look at the vehicle speedometer. To have true force feedback there must be some way of sensing changes in vehicle speed, transmitting that information in real-time and presenting it to the operator in such a fashion that he can intuitively sense how the vehicle is braking. There has been some discussion as to whether the parking (hand) brake should also be actuated as part of the Auto-Park sequence. If this action is included it would be necessary to develop a method of sensing vehicle speed since the parking brake could be damaged if engaged while the vehicle was moving. Also there is the issue of how to reflect correct status of the parking brake on the operator's console if it is engaged automatically instead of manually.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Sensorimotor Requirements for Teleoperation, December 1988

Author(s): Gary Kress and Haren Almaula

OBJECTIVE:

The FMC Corporate Technology Center is currently under contract to TACOM to design and develop a Robotic Command Center. In trying to identify the design requirements for the human-machine interface for the RCC it became apparent that there is virtually no information in the literature related to that issue. Furthermore, there is little empirical data or information in general relating to the issue of sensorimotor requirements for teleoperation. As a result, corporate research funds were used to prepare the present paper which is an attempt to identify some of the knowledge gaps and research requirements in this area.

APPROACH:

Discussion of teleoperation control requirements, sensory requirements for teleoperation, teleoperation technology assessment, assessment of current knowledge on teleoperation, and research requirements.

LESSONS LEARNED:

Studies on the capabilities of the visual system show that the use of color can facilitate object detection and discrimination for most tasks. However, when the color of an object is not relevant to the task, search times can be increased if a color display is used. Anecdotal data from teleoperation field studies indicate that while driving or looking for targets, operators tend to narrow their FOV by concentrating for lengthy periods of time on a limited area. A narrow camera field of view is also required to increase display resolution. On the other hand, operators report that a wide FOV is very desirable for turning and maneuvering in close quarters and for getting a general orientation with regard to the landscape. The literature on motion sickness however indicates that a wide FOV is a strong contributor to motion sickness. Some laboratory studies show that binocular vision can facilitate depth and size perception for close-in viewing tasks and there is also evidence from field studies to suggest that stereo vision may facilitate the detection of negative obstacles and positioning of objects in the depth plane, especially under reduced visibility conditions. The preponderance of the available studies however suggest that stereo vision does not improve performance significantly compared to two-dimensional viewing. One point often overlooked is that depth cues provided by stereo displays are not the functional equivalent of binocular vision. It is possible that stereo vision may even degrade performance, especially if the optical system is not calibrated or if it turns out that stereo vision causes motion sickness.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Distance and Clearance Perception Using Forward-Looking, Vehicular Television Systems, 1988

Author(s): Dwight P. Miller

OBJECTIVE:

This experiment was designed to measure how well people perceive the size, distance, and clearance of unknown objects using video imagery in an off-road driving environment.

APPROACH:

Two video conditions were tested; color, and black and white. Subjects made magnitude judgements of the separation and distance of two vertical columns of unknown height and diameter. The columns were placed four different distances apart and video clips were recorded from four distances. Perceived clearance was tested by having the subjects indicate if they thought a particular vehicle could be driven between the columns. After making distance and clearance judgements, subjects were also asked to estimate the height of the columns.

LESSONS LEARNED:

The tests showed significant differences between the means of transformed distance estimates for black and white, and color. Distance estimates were larger in the color condition. The color condition also showed a greater percentage of errors of over-estimates. Mean height estimates in the color condition were significantly larger than the black and white. The amount of overestimation tended to increase with distance. These results may have considerable impact on the design of teleoperated land vehicles for military applications. Remote drivers, if over-estimating distances and clearances, will get too close to objects before correcting their route, and attempt to drive through gaps that are too narrow. Designers of military teleoperated land vehicles may wish to more closely study the effects of using color-video systems.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Evaluation of Foreground Effects on Video Spatial Perception, 1988

Author(s): Carla U. Smith and Dwight P. Miller

OBJECTIVE:

This study evaluates how well people perceived two objects of unknown size in three different terrains.

APPROACH:

Ten subjects estimated the size, distance, and clearance of the two objects using video tapes produced by a forward-looking, hand-held camera. Terrain variations included a field of grass, a barren construction site, and a high desert mesa.

LESSONS LEARNED:

Results indicated that subjects typically underestimated distances, and, when in error judging clearance, tended to overestimate the gap between the objects. Color provided a slight advantage in estimating clearance over monochrome. The changes in terrain proved to have minimal influence on judging distances.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Evaluation of Vision Systems for Teleoperated Land Vehicles, 1988

Author(s): Dwight P. Miller

OBJECTIVE:

This paper describes a pilot study that compares vision systems that might be used to control a teleoperated land vehicle.

APPROACH:

The study compares three forward-looking vision systems in two modes of driver interaction: 1) actual remote driving and 2) noninteractive video simulation. Remote driving has the advantage of realism but is subject to variability in driving strategies and can be hazardous to equipment. Video simulation provides a more controlled environment in which to compare vision-system parameters, but at the expense of some realism.

LESSONS LEARNED:

Results demonstrate that relative differences in performance among the visual systems are generally consistent in the two test modes. A detection-range metric was found to be sensitive enough to demonstrate performance differences viewing large obstacles using black-and-white and color vision systems. Consequently, future experimentation, aimed at optimizing vision-system parameters, will rely to a greater extent on the more cost-effective, video-simulation approach.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Evaluation of TOV Urethane "Ears", 3 February 1989

Author(s): C. Metz

OBJECTIVE:

To present the results of testing to determine the effectiveness of urethane "ears" for the TOV system.

APPROACH:

Discussion of test procedure, test results, conclusions, and recommendations.

LESSONS LEARNED:

Silastic anthropomorphic ears have been used on the TOV mobility head to produce binaural hearing. The problem with these ears is that they tear easily, have to be glued onto the mobility head and are expensive to replace (approximately $250/pair). It was desired that ears made of a sturdier material with a hard mount be constructed. The design is based on the configuration of a binaural headphone/microphone JVC Model #HM-200E. The difference in average response times between the first and second tests seems to be generated by the fact that the subjects were more familiar with the test procedure the second time around and more apt to have developed a technique for quickly locating the sound (I speak from experience as I was subject #2). The slower response times for locations in front of and behind the vehicle were anticipated as the microphone is shielded by the ear pena in these two positions. I recommend that the urethane ears be used on the mobility head since the test indicates that they provide adequate hearing to the operator. During mobility testing of TOV #2 in Hawaii the urethane ears were used exclusively and were more than adequate for the purpose of communicating with test team members and monitoring engine noise. In addition, the mobility pan & tilt assembly was taken on and off the vehicle and stored on the rear fender multiple times without damage to the ears (it was during this procedure that the silastic ears tended to tear). If high precision aural tracking of targets is required I recommend that further testing be performed to quantitatively evaluate the aural characteristics of both types of ears. In addition the quality of the audio system in general will have to be tested to determine if it is adequate for precision tracking tasks.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Vision System Testing for Teleoperated Vehicles, March 1989

Author(s): D. E. McGovern and D. P. Miller

OBJECTIVE:

This experiment investigated three features of video systems which are thought to have significant impact on control of teleoperated vehicles. These are: color video, black and white video, and steering-slaved camera pointing control.

APPROACH:

Three levels of vision system quality were tested under conditions of remote driving and video simulation: 1) steering-slaved color CCD camera, 2) color CCD camera fixed to the vehicle with the color turned off at the monitor, and 3) fixed CCD camera with the video presented in color. This made is possible to compare color to black and white with the same resolution and field of view, and also fixed camera to steering-slaved camera control with the same resolution and color condition. The tasks of the subjects were to detect and identify obstacles while the vehicle traversed a marked off-road course and to watch simulated gauges and indicate when the readings went out of tolerance. The control console contained a center monitor which displayed the driving video, and a left monitor which was a graphic display of gauges. The test course was one mile long and consisted of a variety of natural terrain and objects (obstacles).

LESSONS LEARNED:

No significant differences in identification of objects were found among the six experimental conditions. Detection-range performance varied greatly across obstacles with variability across subjects. A color advantage of nine feet (out of 60 feet) on detecting obstacles was statistically significant when the data from both color conditions were combined. Data from the questionnaire was generally consistent in that subjects in both the simulation and driving conditions gave higher subjective ratings for color. Subjects recommended that sound be added to help convey information on vehicular status. No advantage was found for steering-slaved cameras. There was a slight advantage of color in the perceptual identification of objects at far distances, but it was not significant. Subjects have a strong preference for color which may cause it to be psychologically important.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: The Effect of Color and Texture of Foreground on Size and Distance Perception Using Video Systems for Teleoperated Vehicles, July 1989

Author(s): C. U. Smith and D. P. Miller

OBJECTIVE:

This experiment was designed to resolve performance differences found in an earlier experiment (SAND88-1958) by exploring the effects of foreground texture and color on estimating distances. Two hypothesis were tested: 1) Color enhances the visual texture of the terrain, giving the images more apparent depth, and 2) The predominate foreground color (green) caused the scene to appear farther away because short wave-length light is subjected to more deviation by refraction in the eye than longer wavelengths.

APPROACH:

Subjects made judgements of the separation and distance of two white vertical columns of unknown height and diameter just as in the earlier experiment. The columns were video taped on three different terrains: green grass, brown sand, and mixed green and brown mesa. Backgrounds and lighting conditions were all similar. Video tapes were recorded at four distances. Two separation distances were used for the clearance judgements. Each subject experienced all terrains and distances in both color and black and white. After running all video conditions, subjects made four direct-vision distance estimates and column height and diameter estimates outside in the mesa terrain.

LESSONS LEARNED:

The response variability was large among subjects and they tended to underestimate actual distances. Estimates for mesa terrain were about four percent higher than sand or grass. Color, unlike in the previous study, was not a significant factor influencing distance estimates. Statistical tests showed that none of the experimental factors had a significant effect on the percentage of correct distance estimates. Subjects tended to underestimate the field distances. The overall terrain did not have a considerable effect on clearance judgements. The percent of incorrect judgements was considerably lower for color than black and white under grass conditions and mesa, but not for sand. The results indicate that changes in the texture of the foreground do not radically alter the perception of distance. Seeing the results of the task being performed, the argument for using color in off-road remote driving video systems cannot be strongly supported.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV #2 Navigator Calibration, 10 August 1989

Author(s): A. Y. Umeda

OBJECTIVE:

To present a discussion on the installation and calibration of the Magnavox MX6102B Terrain Navigation Aid (TNS) for TOV #2.

APPROACH:

Discussion of software upgrade, flux gate compass, calibration, tests, and results.

LESSONS LEARNED:

Tests conducted on 3 August 89 show that the Magnavox MX6102B TNS can be used to provide useful information to the TOV operator if properly calibrated. During the course of two runs through several checkpoints and a combined distance in excess of 10 km, the TOV TNS provided data with errors varying from 0.5% to 3% of distance travelled. This is approximately equivalent to the advertised specificati It is difficult to determine what the actual error is because the calculation of error must be based on a known reference. UTM maps available for this and most areas are scaled 1:25000 resulting in map reading difficulties. Map reading errors are probably in the 10-20 meters range. Although a comparison is made between the TOV navigator and the Magnavox van navigator, there seems to be a conflict of interest involved when the reference navigator is of the same type as the tested navigator. However, the Magnavox navigator is augmented by a supposedly accurate GPS navigator and I tend to have more confidence in this reading than on a reading off a map. Mr. Wanous gave me an estimate of the cost involved with providing direct UTM data through the RS-422 serial port. This software upgrade would also allow position change inputs through the serial port. Quoted cost for this upgrade is $39,000.00. Mr. Wanous is also anticipating a new navigation product which combines MX6102B TNS features with a GPS receiver. This product provides GPS updates when they are available and TNS type updates otherwise. Cost when introduced should be significantly less than the MX6102B. GPS systems can also be used in differential mode with accuracy as good as +/- 2 meters, regardless of military lockout code implementation.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Stereo Vision Driving Trial, 30 October 1989

Author(s): Dr. C. P. Blackman

OBJECTIVE:

To present the results of a driving trial to investigate the use of stereo vision for remote driving.

APPROACH:

The first part of the trial consisted of driving around the main part of the test track. Subsequently the vehicle was driven through a "slalom course" on the straight and level. Seven different drivers were used.

LESSONS LEARNED:

For normal driving (two different drivers) the stereo display was perfectly adequate but the performance was no better than with ordinary video pictures. This was, of course, the expected result given that normal human stereo vision is not thought to play a significant role in driving. In terms of speed, positioning, and number of posts hit, there was no significant difference between normal and stereo vision. Interestingly almost all the drivers reported that stereo vision "felt more comfortable" than normal video, but they were not able to be more specific. The limited trials that time permitted are clearly not a definitive study of the effect of stereo vision on remote or indirect driving. Any such experiment would pay close attention to learning factors and optimum camera position, neither of which were pursued here. Nonetheless it does seem fairly clear that no dramatic improvements over normal video driving are probable were a stereo system to be used. The place for stereo vision appears to be in short range missions for which fibre optic communications are possible and where fine control either of the vehicle or of its payload is required.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV Stereoscopic Video System Alignment Procedure, 8 November 1989
Author(s): Stephen W. Martin

OBJECTIVE:

The following procedure is to be used to align the stereoscopic video system of the TOV. This includes the two separate stereoscopic subsystems; the video camera pair, and the HMD. The procedure is specific to the TOV system, but may be generalized to many stereoscopic video systems which utilize parallel optics helmet mounted displays. Alignment procedures for flat panel stereoscopic systems differ in several regards.

APPROACH:

The camera alignment consists of two components, first setting up the camera/lens combination individually in the laboratory. The camera/lens setup is done to match the camera's light levels, agc loops, and geometries (geometric setup not required for solid state cameras, but a major setup problem with tube type cameras). The second part of aligning the cameras consists of properly doing the physical alignment for the two cameras as a stereoscopic pair. The goal is to align the two video cameras on parallel optical axis, that is to set the stereoscopic window to infinity. The procedure basically uses a video target and electronic video frame/field sequential video switch box. The cameras must be genlocked precisely such that both line one scans start simultaneously. By viewing the video output from the frame sequential unit, one may adjust the cameras such that the images have no relative roll or pitch and they are parallel.

LESSONS LEARNED:

Reverse video is often times not noted by even experienced users of stereoscopic displays, while some users can not even fuse the reverse stereo. The best method for checking that the stereo is not reversed is putting an obstruction (hand, piece of tape, etc) in the field of view of only one camera and making sure the corresponding monocular display video is the one which shows the obstruction. This should be done routinely with the TOV system as not only physical cables, but software, can cause stereo reversal. Be aware that items very close to the video cameras may have to much disparity to comfortably fuse the images in the HMD. This should not be a problem if the video cameras have an interocular separation of the optical axis of 66 mm +/- 1 mm, but is this separation is larger (eg. as of 11/89 the TOV #2 cameras are at around 75 mm separation) some people may have difficulty in fusing objects such as the TOV gearshift lever, steering wheel, etc.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	A Simulated Test of the Effects of Image Jitter on Teleoperated Driving, 1989
Author(s):	Robert E. Cole, Edward H. Spain, Daniel Iki and S. Takata

OBJECTIVE:

To investigate the effects of vertically oscillating TV images (Jitter) on obstacle detection.

APPROACH:

Twenty college students were used in each of three studies. In Experiments 1 and 2 drivers viewed symmetrical patterns of images jittering at various combinations of frequencies and amplitudes recorded at 2 vehicle speeds. In Experiment 3 drivers saw asymmetrical jitter patterns.

LESSONS LEARNED:

Detection times increased in proportion to frequency with a greater rate of change at higher amplitudes and vehicle speeds. Symmetrical jitter can severely degrade remote driving performance by reducing the driver's ability to detect obstacles, and by increasing fatigue, eye strain and motion sickness. Scaled visual disturbance scores also increased with frequency and amplitude of oscillation but not with vehicle speed. Asymmetrical patterns do not appear to increase either detection time or amount of visual disturbance.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: CALEB Stereoscopic Display Variants, 9 January 1990

Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present information on stereoscopic display systems.

APPROACH:

Discussion of advantages, time sequential stereoscopic displays, head mounted stereoscopic displays, and stereoscopic alignment considerations.

LESSONS LEARNED:

The volume, weight and power consumption of the stereoscopic display are comparable to a non-stereoscopic display. The stereoscopic display also provides a degree of redundancy built into the system. While it has been demonstrated that stereoscopic vision offers no significant advantages to monoscopic vision in the case of simple, uncluttered views, improved operator performance has been obtained for more rigorous driving situations. The most pronounced improvements from stereo are in the case of unfamiliar, visually cluttered, and generally degraded images. This would be analogous to off road, terrain driving as opposed to highway driving. Stereo provides visual cues which are useful in judging relative distances and orientation of objects and terrain surface features. Head coupling the vision system provides a kinesthetic orientation of the vision system to the operator, which is beneficial in helping properly orient the operator to the remote environment. Alignment and adjustment of a functional stereoscopic system must be made at both the sensor and display ends to provide a properly matched pair of images for the operator. Mismatched images result in eye strain and fatigue with time which leads to simulator sickness type effects. Contrary to popular belief, a properly designed stereoscopic display system, with the appropriate procedures, can be set up and operated with minimal "tweaking". Experience with the UGV TOV development and tests have not revealed any realignment problems once the system is aligned and secured.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Human Factor Recommendations for the Proposed CALEB Vehicle, 25 January 1990

Author(s): S. Schipani

OBJECTIVE:

To present information concerning human factors issues related to the Caleb vehicle.

APPROACH:

Discussion of color vs. black and white; steering slaved cameras; zoom, pan, and tilt featured cameras; field-of-view (FOV), stereovision, depth perception, overlays, pedal controls, steering controls, kinesthetic feedback, and simulator sickness.

LESSONS LEARNED:

Advantages of color over black and white were found to be significant (at 5 to 20 feet) for obstacle detection (McGovern & Miller, 1989). The benefits of using color are seen to be somewhat less significant when weather conditions (rain, bright sunlight) or terrain (flat, desert type) vary. However, the use of color has appeared to cause drivers to overestimate the size of obstacles. Good or bad, subjects have consistently stated that they prefer using color. Zoom features are required for obstacle detection. No significant difference in operating function was realized when comparing the use of a fixed camera versus a steering slaved camera on a teleoperated vehicle (McGovern & Miller, 1989). Larger field-of-views (FOV) proved significantly better for all forms of driving. However, to give too large a scene to the operator induces simulator sickness. Monitor size that conform to the above is approximately 13 inches (though successful driving has been accomplished when using a monitor size of 9 inches measured diagonally. It is generally recommended that 42 degrees FOV horizontal by 300 horizontal TV lines of resolution (at a minimum) be used. Stereovision was found to improve performance significantly (Silverman, 1982), but only at short distances. The use of stereovision should improve vehicle handling over negative obstacles. Scene minification has been shown to negatively effect vehicle operation and obstacle detection. It is recommended that scene magnification of approximately 25 percent be used to help alleviate this problem. However, caution should be taken to not attempt a panoramic view when driving, as simulator sickness becomes evident under these conditions. Observers have noticed increased reaction time and errors when subjects used a joystick for both acceleration and braking. Whenever possible, at least two motion cues should be presented to the operator. These may be audio, visual, or a combination of the two.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report - SPIE Conference/NPGS Monterey, 20 February 1990

Author(s): Hugh Spain

OBJECTIVE:

This memo documents my attendance and participation in the Stereoscopic Displays and Applications Conference which was part of the 1990 SPIE/SPSE Symposium on Electronic Imaging held in Santa Clara, CA on 11-14 February 1990. It further documents a one-day visit to Dr. Morris Driels and others at the Naval Postgraduate School in Monterey, CA on 15 February 1990.

APPROACH:

Discussion of Monday's Session, Tuesday's Sessions, Wednesday's Session, Wednesday's Demo Session, the visit with Dr. Morris Driels of NPGS, and the visit with Drs. McGhee, Cristo, and Kwak of NPGS.

LESSONS LEARNED:

Stereopsis, relative motion, and interposition were found to be the dominant cues to depth in televised scenes. Generally, when more cues are present in a scene, a proportionately more salient sense of depth is conveyed. Inclusion of relative size, luminance, and interposition cues produced significantly faster depth judgements. However, stereopsis didn't result in significant response time effects though stereo displays did improve ratings of subjective image quality. Test results showed that transitioning from a stereo display to direct view has no more effect on direct view stereoacuity than transitioning from a non-stereo display. Peter Schweiller described stereo video systems devised to date for use by the British nuclear industries. Of particular interest was a stereo camera system that they have built which uses lateral lens separation instead of camera tow-in to achieve stereoscopic convergence. Though this is not a new concept and it is known to eliminate vertical disparities which are antithetical to comfortable viewing, this is the first instance to date in which the technique has been successfully implemented on video. Bob Cole presented results from an extensive set of studies comparing stereo and mono viewing for tasks designed to minimize non-disparity depth cues. A detailed report of his findings is on file.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Experiences and Results in Teleoperation of Land Vehicles, April 1990

Author(s): Douglas E. McGovern

OBJECTIVE:

To discuss experimental findings and the results of accumulated operational experience.

APPROACH:

This paper attempts to expand the teleoperation data base through a presentation of some of the results of experimentation in teleoperation at Sandia National Laboratories and through discussion of the observations of SNL personnel gathered over several years of teleoperation experience.

LESSONS LEARNED:

All of the accidents involving teleoperation (inside-out control) have been rollovers. It was found that object and obstacle detection were not sensitive to camera differences. This did not support the initial hypothesis that color video and steering slaved camera control would result in superior operation. Objects were detected as well with a fixed, B/W camera. Range data were sensitive to camera differences. When objects were detected, they were detected at a greater range when color was used. Color provided a fairly consistent 5 to 20 foot range advantage when compared to B/W video. Size and distance estimation produced inconsistent results. One study indicated that subjects using color video consistently judged the size and spacing of obstacles to be larger than subjects using B/W video. A follow-on study was conducted to investigate foreground texture effects on these size/distance judgement errors. In this study, color was not found to be an influential factor in estimating distance. Subjective assessments and teleoperation test data suggest the possibility of reducing video bandwidth to about 500 kHz. It is very difficult to operate a vehicle in restricted space with a narrow field-of-view. High resolution does appear to be important when many sizes and types of obstacles are present and for operation off-road where identification of best path is important. Work with television surveillance systems has indicated that the increased resolution possible with B/W equipment is much more important than any additional information contained in the color signal. This does not appear true for teleoperation. Color is also rated as very highly desirable in all subjective preferences. Experimentation has not supported a quantitative difference in obstacle detection between B/W and color video. Negative obstacles create difficulty in that operators can not distinguish them from other terrain features which did not affect vehicle travel.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Naval Ocean Systems Center Advanced Systems Division Support for TUGV/Caleb Operator Control Unit Trade-Off Studies, 7 May 1990

Author(s): J. L. Fuqua

OBJECTIVE:

To provide supporting information for the OCU Trade-Off Determination Studies.

APPROACH:

Discussion on Caleb Stereoscopic Display Variants, the AROD Controller, and "TOD for the OCU of the Caleb UGV - Draft 2".

LESSONS LEARNED:

While it has been demonstrated that stereoscopic vision offers no significant advantages to monoscopic vision in the case of simple, uncluttered views, improved operator performance has been obtained for more rigorous driving situations. The most pronounced improvements from stereo are in the case of unfamiliar, visually cluttered, and generally degraded images. This would be analogous to off road, terrain driving as opposed to highway driving. Stereo provides visual cues which are useful in judging relative distances and orientation of objects and terrain surface features. Head coupling the vision system provides a kinesthetic orientation of the vision system to the operator, which is beneficial in helping properly orient the operator to the remote environment. Experience with the UGV TOV development and tests have not revealed any realignment problems once the system is aligned and secured. The volume, weight, and power consumption of the stereoscopic display are comparable to a non-stereoscopic display. The stereoscopic display also provides a degree of redundancy built into the system. Mismatched images result in eye strain and fatigue with time which leads to simulator sickness type effects.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A Novel, Low-Cost Stabilized Driver Module for TUGV Applications, November 1990

Author(s): Marcelo C. Algrain

OBJECTIVE:

This paper presents an analysis of the image stabilization problem as it relates to road surface quality and vehicle speed and establishes the importance of image stabilization as a critical factor to achieving the TUGV's full battlefield potential.

APPROACH:

The new technique uses an arrangement of low-cost miniature linear accelerometers (instead of gyros) to infer angular motion. These are used to generate the gimbal counterrotations required to reject the undesirable angular vibrations associated with the types of terrain encountered during on and off-road operations. This technique retains the motion related to vehicle dynamics, if desired, providing a "feel for the road" and enhancing safety of operation.

LESSONS LEARNED:

In the case of imaging sensors, stabilization is essential for maintaining the detection and recognition ranges. A widely accepted standard is to specify line-of-sight stabilization levels (LOS jitter) below 20 percent of the sensor resolution to keep the degradation in detection and recognition ranges to less than 5 percent. Using the horizontal resolution as the critical dimension, the recommended stabilization requirement for the mobility unit becomes 0.02° (350 μrad). The expected rms jitter at the vehicle body is 2.2° in pitch and 3.4° in roll. The expected jitter is more than two orders of magnitude larger than the maximum allowable to preserve image quality for driver unit sensors. This clearly indicates the need for active stabilization to retain image resolution in spite of the relatively large WFOV of the TV's in the driver/mobility unit. Further benefits of a stabilized image are reduced operator fatigue over the longer driving periods, and minimized susceptibility to motion sickness.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV Mobility Sensor - Night Vision Sensor, 7 November 1990

Author(s): Naval Ocean Systems Center

OBJECTIVE:

To provide the TOV with mobility sensor upgrades which permit night operations.

APPROACH:

A pair of intensified solid state cameras will be integrated in a stereo configuration and be provided as a direct replacement to existing Mobility Sensor units.

LESSONS LEARNED:

Stereo configuration is recommended so that performance comparisons can be made between existing Mobility Sensor units and the upgraded day/night system. It is further recommended that the larger 25 mm format be used to obtain the best possible image under the degraded light conditions as well as during daylight conditions. These cameras are intended to be operable during day and night lighting conditions without adjustment or replacement of the equipment. Automatic iris and electronic means will be used within the cameras to compensate for the severe lighting environment. Color is not recommended since TOV is not equipped to display color in the HMD and because of the relative immaturity of the product (high cost, less robust design).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: High Resolution Stereoscopic Color TV System, 8 November 1990

Author(s): Bernhard A. Hjortzberg

OBJECTIVE:

To provide a description of a high resolution stereoscopic color TV system.

APPROACH:

Discussion of electrical and optical specifications of the high resolution stereoscopic color camera and the high resolution stereoscopic color display.

LESSONS LEARNED:

The stereo camera uses a new CCD from Texas Instruments "TC217" which senses 1134 pixels per line and 972 lines. A sister chip, the TC216, is electrically identical to the 217 and has color striped filters. This system is compatible with dual camera monochrome stereo systems used with HMD. Only a single lens and autoiris is used which eliminates tracking problems. The geometry accuracy of CCDs allows the use of dual sensors driven by a common timer. The left, right image beams are multiplexed for the use of a single focusing lens. The stereo color display consists of a high resolution color monitor with a liquid crystal shutter, viewed through polarized glasses. The stereoscopic image is viewed through fixed orthogonally polarized, neutral grey, glasses. High resolution 1023 pixels by 972 lines image. Color stereo display compatible with monochrome HMD. Viewer not electrically connected to the display. Several persons can view the stereoscopic color display simultaneously in addition to the person viewing the HMD monochrome image. Viewer head location not critical.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Issues in Mobile Robotics: The Unmanned Ground Vehicle Program Teleoperated Vehicle (TOV), 8 - 9 November 1990

Author(s): W. A. Aviles, T. W. Hughes, H. R. Everett, A. Y. Umeda, S. W. Martin, A. H. Koyamatsu, M. R. Solorzano, R. T. Laird, and S. P. McArthur

OBJECTIVE:

To examine the key system and supporting technology issues associated with the design and development of effective general-purpose unmanned mobile robots for operation in unstructured outdoor environments within the context of an advanced telerobotic mobile system developed by the Naval Ocean Systems Center (NOSC) -- The Unmanned Ground Vehicle Program Teleoperated Vehicle (TOV).

APPROACH:

Discussion of the TOV system architecture, TOV high-level robotic control architecture, choice for the remote vehicle, control shelter and control stations, remote vehicle/control station communication system, mission modules, accomplishments, and lessons learned.

LESSONS LEARNED:

Mobility cameras are monochrome, provide 525 TV lines of horizontal resolution over a 40 degree horizontal field of view, and have auto-irises with the ability to handle illumination conditions from dusk to full daylight (1 - 20000 lux). The audio feedback system has a response from 50 hz to 12000 hz and a dynamic range of 146 dB. The navigation system uses SATNAV navigation satellites for position updates and performs dead reckoning in between satellite fixes utilizing a fluxgate compass and a wheel sensor. SATNAV accuracy is +/- 200 meters and dead reckoning accuracy is 2% of distance traveled. This system is directly upgradeable to a 10 meter accurate, 1 second update GPS package. The TOV uses a stereoscopic head mounted display (HMD) system. The vision system is designed so that the operator sees a virtual image of the environment with a 1:1 perspective. The apparent angular subtense of remote objects appears the same as if the operator's eyes were actually at the remote camera's location. TOV system operators had difficulty perceiving the orientation of the remote vehicle. Another common complaint of TOV system operators is the inability of knowing where the vehicle is located in relation to its desired goal or intermediate navigational way-points (i.e. they get lost easy).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Navigation and Retro-Traverse on the RT Vehicle, 15 January 1991

Author(s): Karl Murphy

OBJECTIVE:

This paper discusses the navigation systems and the control algorithms used for retro-traverse

APPROACH:

Two navigation systems were investigated, the Modular Azimuth and Positioning System, MAPS, and the Radio Frequency Navigation Grid, RFNG. MAPS is an inertial navigation/dead reckoning system while RFNG is a global positioning system that uses radio beacons placed at corners of the test site.

LESSONS LEARNED:

Several steering algorithms were used and CMU's pure pursuit algorithm was found to be the best by far and was stable at speeds of 40 mph. MAPS position estimate drifts at a rate slightly more than 0.1% of distance traveled, as determined by driving the vehicle around closed paths of various lengths and returning to the starting position. If the operator drives the vehicle 500 meters out and the vehicle back 500 meters, the MAPS will have drifted 1 meter. Any path following errors will be added to that. The MAPS' accuracy is 2% of distance from the start point. This was determined by driving the vehicle to several surveyed locations and comparing the surveyed data with the MAPS data. This error occurs mainly because the assumed ratio of distance traveled to odometer pulses is too small and hence the MAPS reports that the vehicle has traveled a shorter distance than it actually has. RFNG uses radio pulses from beacons and using triangulation, computes its position. RFNG does not drift, has an estimated repeatability of 0.1 meters, and can be used by multiple vehicles. Unfortunately, the RFNG hardware is very temperamental and was inoperable more times than not. We therefore do not yet know its actual capabilities. Look ahead distance is selected according to vehicle speed. If the look ahead distance is too large, the vehicle will cut corners. If the distance is too small, the controller will be unstable especially at higher speeds. We used 6 meters for speeds up to 15 mph and 12 meters for speeds up to 40 mph.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	Objective Assessments of Mobility With an Early Unmanned Ground Vehicle (UGV) Prototype Viewing System, 6 - 8 March 1991
Author(s):	Edward H. Spain

OBJECTIVE:

This report describes the procedures and specific tasks used in making comparisons across the 4 viewing system options that were compared: 1) direct view, 2) direct view 40¤ by 30¤, 3) monoscopic helmet-mounted display (HMD), and 4) stereoscopic HMD.

APPROACH:

Testing was conducted with two groups of drivers; 1) an "experienced" group who were well practiced on courses run and tested with each of four alternate viewing system options, and 2) an "inexperienced" group who were unfamiliar with courses and tested with a single mobility sensor system option on a one-time basis. Specific results in terms of relative driving efficiencies on 6 driving courses are reported and discussed with respect to their general implications for design of the man-machine interface for safe and efficient driving of UGVs in the teleoperated mode.

LESSONS LEARNED:

Driving time under the direct view options was approximately 15% faster than driving time under video view options. The analysis suggests that if sufficient image resolution, contrast, color, head motion coupling, and accurate feedback of vehicle dynamics are provided to a driver, a 40¤ by 30¤, 1:1 field of view is sufficiently wide enough for low-speed mobility within the scope of fundamental driving task tested in this study. However, the consistency of the pattern of slightly elevated error rates for the direct view 40 x 30 option versus the direct view option does suggest that some capability is lost by restricting a driver's peripheral field of view. Past research and experience has shown that the performance advantages which stereoscopic imagery provides are most pronounced in unfamiliar, visually cluttered, and visually degraded images. Stereo imagery is also known to be useful in judging the relative distances and orientations of objects and terrain surface features - all of which are invaluable to an operator when evaluating the composition and topography of terrain before attempting to traverse it. The results are strongly suggestive of potential performance advantages to be derived by using stereoscopic imagery in display systems.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Remote Vision Systems for Teleoperated Ground Vehicles, 6-8 March 1991

Author(s): Alan Y. Umeda, Stephen W. Martin, and John O. Merritt

OBJECTIVE:

To present a discussion on the utility of features such as stereoscopic vision, color imagery, head-mounted displays, and head-coupled aiming of sensors. Recommendations are provided for the design of future UGV remote vision systems.

APPROACH:

The report was broken up into the following sections: 1) Introduction, 2) TOV Vision Systems, 3) Test and Evaluation, 4) Discussion of Remote Vision System Features, and 5) Summary and Recommendations.

LESSONS LEARNED:

Stereoscopic television displays provide substantial performance advantages over conventional television displays when: 1) aspects of the remote scenes are unfamiliar or are frequently changing, 2) the rate of learning of new tasks is important, 3) image quality is poor, and 4) tasks have significant depth positioning requirements. TOV has two miniature, high resolution video cameras that provide stereoscopic image sensing. These cameras are aligned with parallel optical axes and are separated a distance equivalent to an average human's interocular separation. The video camera lens field-of-view (FOV) is selected to match the apparent display FOV observed by the operator. Automatic iris lenses allow unattended aperture adjustments. A camera convergence set at infinity was used to reduce operator fatigue due to eye strain. Analyses of test data revealed that objects, such as rocks buried in vegetation, and negative terrain features such as potholes and ditches, were difficult and sometimes impossible to discern using monoscopic vision. Anecdotal data from TOV operators indicate that in certain RSTA situations, color improved operator recognition of targets. However, in poor lighting situations, such as near dusk and in shadows, recognition of targets was degraded due to color sensor limitations. The use of "gravity referenced" compensation to video sensors provided more readily interpretable vehicle pitch and roll attitude cues.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Stereoscopic Versus Orthogonal View Displays for Performance of a Remote Manipulator Task, 1991

Author(s): E. Hugh Spain and K.- Peter Holzhausen

OBJECTIVE:

To test the performance of a teleoperator using stereoscopic displays versus orthogonal view displays.

APPROACH:

Discussion of the operator, display interface, camera configuration, line feeder task, measurement of gaze preference, testing procedure, results, and conclusions.

LESSONS LEARNED:

While previous experiments showed an overall ~12% task completion time advantage for a stereoscopic display over a monoscopic display, the present study showed even more pronounced effects of ~26% and ~29% advantages in task completion times over orthogonal and simple monoscopic displays, respectively. Most striking was the concordance between the previous experiment and this experiment with respect to gaze preferences. Whereas, Dumbreck, observed an overall stereoscopic display gaze preference of 94.6%, we observed and overall 95.2% preference. Taken together, the results reported here offer strong support to the general conclusion that stereoscopic displays are advantageous for remote performance of complex, three-dimensional manipulation tasks. In this experiment, when compared to both simple and orthogonal monoscopic displays, a stereoscopic display significantly and substantially lowered times required for overall task completion, improved precision of operations, reduced inadvertent collisions with the taskboard, and was objectively observed to be very strongly preferred when operators were given an immediate choice between viewing either a stereoscopic display or a monoscopic one. A strong, consistent preference was found for the "simple" monoscopic view over the orthogonal monoscopic view.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Techniques for Autonomous Navigation, March 1992

Author(s): R. H. Byrne, P. R. Klarer, and J. B. Pletta

OBJECTIVE:

To evaluate potential technical approaches for implementing the robotic path-following system of the Mobile Detection Assessment Response System (MDARS).

APPROACH:

The report is broken down into path sensing and position location. Various path sensing techniques and position location systems are discussed. A cost-risk trade-off analysis of each system is provided along with recommendations on the best technical approach to meet the MDARS path-following requirements using proven technology.

LESSONS LEARNED:

The Surrogated Teleoperated Vehicle (STV) is assumed to be the base vehicle chosen for this application. Machine vision, sonar, and LADAR range mapping not recommended due to high technical risk. Wire-following was recommended as the primary candidate technology and the Kaman RFNG system was recommended as a secondary candidate system.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	Unmanned Ground Vehicle Best Technical Approach, Progress Review Meeting Summary, 29 April 1992
Author(s):	Dr. James Baumann and Larry W. Brantley

OBJECTIVE:

To provide a summary of information, issues, and recommendations discussed at the Best Technical Approach (BTA) meeting.

APPROACH:

Provide a bound report including a summary sheet and viewgraph materials discussed during the meeting.

LESSONS LEARNED:

Available documentation concerning UGV mission profiles indicates a larger HMMWV-type vehicle while others indicate a smaller All-Terrain Vehicle. The proponent could help in prioritizing the theories of employment (TOEs). Acoustics could justify UGV existence in Air Defense roles as a triggering system for helicopters and fixed wings.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A General Formula for Calculating Camera Positioning for Remote Driving, 1992

Author(s): U.S. Army Human Engineering Laboratory (HEL)

OBJECTIVE:

To identify proper camera locations to meet given constraints pertaining to the teleoperator's view.

APPROACH:

Discussion of constraints concerning the teleoperator's view and then an example calculation is worked for purposes of illustration.

LESSONS LEARNED:

Sky-to-Ground Ratio: The percent of sky to ground should be no less than 15% and no greater than 50%. Close-in Vision: The remote driver should be able to view the ground 20 feet (preferably 10 feet) in front of the vehicle and beyond (MIL-HDBK 759). Vehicle Reference: The amount of vehicle hood in the teleoperator's view should be no less than 1 foot but no greater than 5 feet. The teleoperator's view should not extend into the vehicle dash. The edges of the vehicle's front fenders should be visible to the teleoperator. It is highly desirable that vision beyond the edges of the front fenders also be provided. For illustration purposes, a 1/2 inch CCD camera with a 6-mm lens was used. The 6-mm lens provides a vertical field-of-view (VFOV) of 42 degrees and a horizontal FOV (HFOV) of 55 degrees. For any focal length, the maximum of 50% sky occurs at a camera angle of 0 degrees. For a 6-mm focal length and 4.8-mm imager frame, a minimum 15% sky occurs at a 14.7 degree camera angle below the horizontal.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: An Assessment of Camera Position Options and Their Effects on Remote D.iver Performance

Author(s): Monica M. Glumm

OBJECTIVE:

To determine the effects of camera position on remote driver performance.

APPROACH:

Procedures for conducting the experiment and collecting and evaluating data were established. Candidate drivers were selected. Experiments were conducted with 18 participants.

LESSONS LEARNED:

Camera positions #1, #2, and #3 correspond to positions #8, #9, and #10 (on page 10), respectively. 80 % of participants preferred position #1 while the rest chose position #3. Speed was greater with position #1 and errors occurred more (traffic cone hits) with position #3. Parking performance was better with position #3. Camera used was 6 mm lens (Sony; Model SSC-C350) with 55 degree horizontal and 43 degree vertical field-of-view.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	An Experimental Study of the Effects of Field-of-View on Remote Driver Performance
Author(s):	Monica M. Glumm

OBJECTIVE:

To determine the effects of field-of-view on remote driver performance.

APPROACH:

Procedures for conducting the experiment and collecting and evaluating the data were established. Candidate drivers were selected according to a set criteria. Experiment was conducted with 18 participants.

LESSONS LEARNED:

Overall, greater speeds and accuracy were achieved with the 6 mm lens (55 degree horizontal FOV) camera. Use of the 3.5 mm (94 degree horizontal FOV) camera yielded better obstacle avoidance performance. Participants preferred 6 mm lens camera.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Assessments of Maneuverability With the Teleoperated Vehicle (TOV)

Author(s): Edward H. Spain

OBJECTIVE:

This report describes the procedures and specific tasks used in making comparisons of maneuverability across the various viewing system options tested.

APPROACH:

The procedures were run with two groups of drivers, well-practiced civilian personnel who were tested with each of the viewing systems and enlisted Marine personnel who volunteered to be tested with a single mobility sensor system on a one-time basis. Specific results in terms of times through courses, steering, and braking accuracy are reported.

LESSONS LEARNED:

Statistically significant differences were found for each of the 6 measures taken in the fundamental mobility test battery, and all differences found showed the Direct View condition to be superior to the Direct Drive with Video View conditions tested. The findings suggest that if sufficient image resolution, contrast and color head motion coupling, and accurate feedback of vehicle dynamics are provided to an operator a 40° by 30° FOV is sufficiently large enough for low-speed maneuverability under the conditions tested. Under the driving conditions tested, stereoscopic imagery provided no significant advantages over a simpler monoscopic imagery. In attempting to generalize this finding to more rigorous driving conditions, however, one must remember that past research has shown that the advantages stereoscopic imagery provides are most pronounced in unfamiliar, visually cluttered and in visually degraded scenes. Stereoscopic imagery is also useful in judging the relative distances and orientations of objects and terrain surface features - all of which might prove invaluable to an operator in "reading" terrain before attempting to traverse it. Results suggest that better matching to direct view spatial correspondence may provide improved performance. They do not preclude the possibility suggested by a substantial body of data that a slight magnification of the scene through the video system might provide even greater improvements in driving performance.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Development of Remote Presence Technology for Teleoperator Systems

Author(s): J. D. Hightower, D. C. Smith, and S. F. Walker

OBJECTIVE:

The Naval Ocean Systems Center (NOSC) has a broad spectrum research and development program to establish the technology base required to provide remote presence to teleoperated systems. This paper briefly describes the overall program and various key technology areas being pursued.

APPROACH:

Discussion of background, terminology, current NOSC efforts, fiber-optic communication linkages, stereoscopic visual displays, computer image processing, and future directions and plans.

LESSONS LEARNED:

Lightweight, Kevlar - reinforced cables with diameters ranging from 1.2 mm to 1.8 mm have been prototyped, wound into canisters, and have been successfully deployed from a variety of vehicles. A major design goal is to achieve uniform application of a suitable elastomer jacket for abrasion and crush resistance of a 1.5 mm cable for improved land vehicle applications. Stereo television displays provide substantial performance advantages over conventional television displays when: 1) aspects of the remote scene are unfamiliar or are frequently changing, 2) rate of learning of new tasks is important, 3) visibility is poor, and 4) tasks have significant depth positioning requirements. Following successful demonstrations of stereo television's advantages, the effects of several stereo television parameters on additional perceptual measures such as depth resolution and depth interval estimations were investigated. The stereo TV parameters investigated included: 1) camera interaxial separation, 2) lens magnification, and 3) introduction of motion parallax produced by coupling operator head movements with a remote pair of cameras. In all cases, specific values for each of the parameters were found to improve system performance over and above levels typically used in stereo TV viewing systems.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Effects of Camera Aiming Technique and Display Type on Unmanned Ground Vehicle Performance

Author(s): Edward H. Spain

OBJECTIVE:

To assess the separate and combined impact of three alternate camera aiming techniques and two display types on driving performance with a prototype remotely operated ground vehicle.

APPROACH:

Camera aiming techniques and display types chosen for testing were selected based on current reliable implementable design options. Two different driving courses were employed to measure the ability of a UGV to maneuver into and out of tightly-confined areas and to measure the ability of a UGV to visually scan an unfamiliar course for waypoints and to drive throught these waypoints in a specified sequence while scanning for, reporting, and avoiding man-made and natural obstacles.

LESSONS LEARNED:

Head movement aiming (using a helmet-mounted display) increased performance for maneuvering into and out of tightly confined spaces. Helmet-mounted display and both head movement aiming and joystick aiming caused teleoperator induced uneasiness. Head movement aiming technique recommended for us in UGV. Problems with fiber optic cable included cable costs, damage and repair, and retrieval time. RF link recommended for testing.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Evaluation of Stereoscopic Display Benefits

Author(s): John O. Merritt

OBJECTIVE:

This paper lists some of the side-benefits and evaluation factors that should be considered when deciding between 2D versus 3D displays for a given application.

APPROACH:

Discussion on effective image quality, visual noise filtering, visual attention localization, variable field of view, luster, scintillation, surface sheen, terrain slope perception in off-road driving, sense of forward speed, operator workload relief, and focus/fixation control.

LESSONS LEARNED:

A stereoscopic display can help make up for poor image quality due to low resolution, limited gray scale, defocus, motion blur, impaired visibility, etc., because binocular depth cues are generally less dependent on image quality than are monocular depth cues. Visual noise (both static and dynamic) can be separated from the signal (actual scene objects) when two independent images are presented in a 3D display. With binocular vision, the brain can easily separate the correlated "signal" from the uncorrelated "noise." This can provide critical signal-to-noise improvement for sensors that have inherently poor signal/noise ratio, such as low-light-level TV or FLIR (forward looking infrared). The signal/noise ratio improvement has been measured at about 3 dB. Using binocular vision, an observer can easily look through visual clutter (such as broken foliage in the foreground), concentrating visual attention on objects in a specific depth plane. A stereoscopic system can provide a wider total field of view (FOV), while maintaining the same maximum level of horizontal resolution (as obtained with a given sensor, such as a FLIR of CCD imaging chip), by partially overlapping the left-eye and right-eye formats. Foe example, with 50% overlap, two 60 degree fields can provide a total FOV of 90 degrees with a 30 degree binocular overlap region in the center. Tests comparing 2D versus 3D stereo displays in off-road driving have shown that perception of terrain slope is significantly better with a 3D display, whereas it is difficult and error-prone with a 2D display. These tests suggest that motion parallax and other monocular depth cues do not supply enough information to make up for the lack of binocular parallax depth cues in a 2D display.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Research Issues Involved in Applying Stereoscopic Television to Remotely Operated Vehicles

Author(s): Ross L. Pepper, Robert E. Cole, Edward H. Spain, and John E. Sigurdson

OBJECTIVE:

This report provides a brief, general overview of an ongoing program of research at the Naval Ocean Systems Center (NOSC), Hawaii Laboratory, to assess the value of three-dimensional imagery for the control of remotely operated work systems. The effects of visibility conditions, learning, task demands, pseudo-movement parallax, hyperstereopsis, and isomorphic linkage of camera movements to operator head movements are discussed.

APPROACH:

Our approach to this problem has been the development of a test facility and a set of experimental procedures to evaluate man-machine interactions in teleoperators, machines designed to communicate man's perceptional, problem-solving and manipulative skills into hazardous and remote environments. Our recent efforts have been directed toward the development of a "general purpose" teleoperator, one capable of effective operation across a wide range of environments and tasks, especially those encountered in the ocean depths.

LESSONS LEARNED:

Over a wide range of studies using different sensor/display systems, tasks and operators, we have found an approximate two-fold gain in stereoacuity in the transition from monoscopic to stereoscopic TV viewing conditions. For each of our studies involving comparisons of stereo and monoscopic TV systems, stereo viewing has always produced superior performance even with camera separation set at half the normal human interocular distance. Furthermore, performance advantages associated with stereo displays were more pronounced under visually degraded viewing conditions. As camera separation was increased to the normal interocular distance and beyond into the region of hyperstereopsis, we observed a gradual gain in stereoacuity to a level approximating and in some cases even exceeding that found under direct viewing conditions.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

PAYLOAD

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Letter Report: TMAP Sensor Suite, included in the document entitled Low Cost Sensor Suite Candidates for an Anti-Armor Robot, 30 April 1985

Author(s): W. E. Miller

OBJECTIVE:

To document technical progress on the sensor suite task on the Anti-armor Robot by the Advanced Sensors Directorate. Several decisions as to the functional approach and the specific hardware we will implement have been made, and some investigations into expected performance capabilities completed. Description of the suite configuration is being published in "Proposal for Robotic Sensor Suite Evaluation", draft provided in September. Six elements of the suite will be addressed.

APPROACH:

Discussion of night sights, television cameras, radar guns, acoustic sensors, lasers, and sensor fusion.

LESSONS LEARNED:

The Texas Instruments CAT has been selected as the best overall Thermal Imaging sensor. This was due in a large measure to the lowest projected unit cost ($4,700 at the end of the present development effort), and also to the fact that it is an uncooled device of reasonable performance. A three camera configuration has been chosen: an 8:1 zoomed color camera aligned with the sensor suite forward axis, with two identical cameras aimed to either side to provide peripheral vision for vehicle driving and flash detection when searching for targets. Only the central camera will have the zoom mechanism operable, but all three have internal auto-focus and auto-iris functions to relieve the operator of these tasks. The total field of view is 105 degrees with the small cameras purchased. The rationale used to select these particular cameras deserves some discussion. They are JVC home video units, bought off the commercial market after a survey of capabilities. Of particular note is the price - a selection of cameras with slightly different characteristics is available for $600 to $800; the model purchased was $650. The performance features are very similar to a militarized camera, the TCS-500. Two very significant differences should be highlighted however: 1) The commercial camera is not militarized, and will likely be less reliable in the field (Setter has never had a failure of their similar cameras); and 2) The commercial camera, at $650, is markedly lower cost that the equivalent militarized unit at $14,000! Two sets of dual cardioid microphones catalog number 33-1071 were used for acoustic sensors. Time required for tank location in adverse conditions of wind and rain was: 1) visual only - 42 seconds, 2) stereo sound - 35 seconds, and 3) both - 12 seconds.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	OPS Plan for 11 - 12 July 1985 Teleoperator Controlled Vehicle Remote Weapon Firing at Ulupau Crater, 10 July 1985
Author(s):	D. C. Smith

OBJECTIVE:

To demonstrate the remote firing of an M-60 machine gun mounted on a teleoperated vehicle.

APPROACH:

Discussion of equipment and materials, operating procedures, M60 setup and firing sequence, hang-fire power down sequence, and planned safety precautions.

LESSONS LEARNED:

Hang-Fire Power Down Sequence: 1) release FIRE switch; 2) turn off vehicle engine from Control Station (shuts down Pan/tilt Mechanism); 3) approach vehicle from the side; 4) close pneumatic shut off valve; 5) turn off pneumatic pressure bottle; 6) observe condition of Triggering Mechanism; 7) If Triggering Mechanism is depressing M60 trigger, then attempt to release Triggering Mechanism by one or both of the following steps: a. release air pressure at the actuator by disconnecting pressure line and b. unbolt Mechanical Linkage from Air Piston Cylinder; 8) when Triggering Mechanism is released, place Trigger Safety to ON; 9) detach Triggering Mechanism from M60 trigger; and 10) remove unspent live rounds from M60 (Armorer). Planned Safety Precautions: 1) The M60 Machine Gun will be rigidly mounted on a Pan/Tilt Mechanism which is attached to the roof of a remotely controlled vehicle. Mechanical stops on the Pan/Tilt Mechanism limit the range of azimuth (pan) and elevation (tilt) angles which prevents rounds from straying outside of the firing range area in the event of system control failure or glitches. Pan angular limits are 5 degrees to either side of center (10 degrees total). Tilt angular limits are 10 degrees down and 15 degrees in the upward direction; 2) Live rounds will be handled by experienced M60 armorers. Live rounds will not be attached to M60 when vehicle is moving; 3) The Triggering Mechanism will not be attached to the trigger during loading and unloading of the weapon; 4) Two-way voice communications will be established between the Control Station operator and personnel located at the vehicle; 5) Vehicle will be set to "park" gear during setup and firing of weapon. In addition, the electric parking brake will be set to insure that the vehicle is immobilized during the setup and firing procedures; 6) The ammunition belt will be configured or trimmed to allow only 10 rounds to be fired at a time which will limit the number of inadvertent shots that can be fired during a system failure; and 7) A pneumatic shut off valve is accessible to prevent pressurized air from reaching the air piston cylinder. When this valve is closed, the M60 trigger cannot be actuated by the Triggering Mechanism.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Effects of Extended Camera Baseline and Image Magnification on Target Detection Time and Target Recognition with a Stereoscopic TV System, February 1986

Author(s): E. H. Spain

OBJECTIVE:

Increase the effectiveness of hyperstereoscopic viewing techniques for terrestrial reconnaissance.

APPROACH:

Discussion of stereoscopic perception, prior research, military applications, image collection, target-background considerations, observer screening, visual performance testing procedure, experimental results, and conclusions/recommendations.

LESSONS LEARNED:

When viewing conditions are poor and monocular cues to depth and distance are degraded or absent, stereopsis helps a viewer discern the form, location, and orientation of objects, and this gives him better control of the environment. Stereopsis provides a rapid, automatic anticlutter, anticamouflage mechanism requiring only low-level preconscious processing, freeing cognitive resources for higher level tasks. Both image magnification and increases in camera interaxial separation are useful strategies for enhancing target detection time and recognition rate with stereoscopic TV systems. The interactive effects of image magnification and variable camera interaxial separation were not disruptive of visual performance for remote reconnaissance tasks.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Slew Rate Required to Acquire and Track a Moving Target, 26 February 1986

Author(s): R. L. Remick

OBJECTIVE:

To determine what the maximum slew rate should be for a remote platform using TOW/Dragon.

APPROACH:

Discussion of the speed capabilities of current Soviet armored vehicles, tracking slew rate requirements, and acquisition slew rate requirements.

LESSONS LEARNED:

Dragon and TOW have six degree field-of-view optics and a minimum 65 meter range for warhead arming to occur. A slew rate of 8.6 deg/sec is sufficient to track a 35 kph target. If the target speed does not exceed that of a Soviet tank (50 kph) then a 18 deg/sec slew rate capability is required. If acquisition and tracking of all Soviet armored vehicles is required, then a slew rate of 30 to 35 deg/sec would be appropriate.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOW Anti-Tank Missile System, Appendix B, Phonecon, 26 March 1986

Author(s): R. L. Remick

OBJECTIVE:

To discuss issues related to digitizing color and black/white TV signals.

APPROACH:

Discussed black/white TV, color TV, multiple TV's, TOVX and ATV.

LESSONS LEARNED:

For black/white NTSC type TV signals, the required sample rate is straight forward to calculate using the sampling theorem and knowledge of the system's filters. I mentioned 2.5 x BW as a rate and Duane said this should work okay. For color TV: Can not just sample the same way as for B/W TV. The problem is the color burst. The color information is related to phase and the color burst is transmitted as a reference to lock up the oscillator in the receiver. If the sample rate is not fast enough to preserve phase, then the colors on the receiver screen will all be off-color. Duane said to use a master clock for the communication bit stream and use it to provide the color reference and synchronize the TV cameras. Duane has used a 3X sample rate for color where he has synchronized his sampling with the color burst. He said the 3X was based more on convenience than on the actual value. It is easier to generate a whole number than parts of a number in logic circuits. He said if there are multiple TV cameras, and especially if there are B/W and color in the same system to synchronize all the cameras to the same color line rate. Otherwise, the differing line rates between cameras (B/W has a different line rate than color) will show up as faint pictures rolling through the monitors superimposed on the principle scene. Cross-talk 40 dB down between vision systems is detectable by the eye if the systems are not synchronized together. He said in systems such as TOVX and ATV, where there is a mix of analog and digital systems, to synchronize all the systems together. The TV video signal is analog but it contains sync signals for vertical and horizontal sync. Do not let things go asyncronously. He said the cross talk and interference will be a real headache.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Human Factors Affecting AROD Design, Training, and Operations, January 1987

Author(s): Stanley N. Roscoe, Louis Corl, and Donald H. Couchman

OBJECTIVE:

To present human engineering principles of AROD system design, training, and operation.

APPROACH:

Discussion on missions, functions, requirements, functional allocations, system definitions, design constraints, camera considerations, remote presence, simulation fidelity, helmet position sensing, and radio considerations.

LESSONS LEARNED:

In a study reported by S. M. Luria (1969), the effect of field-of-view on stereoscopic and resolution acuity was measured. No effect was found on binocular resolution acuity for fields-of-view ranging from unrestricted to 3.8 degrees. This acuity was measured with grating targets presented at about 5.36 meters. There was a loss of stereoscopic acuity as the field-of-view was decreased between the unrestricted case and the 3.8-degree field-of-view amounting to a factor of five in the means for eight subjects, as measured using a Howard-Dolman apparatus with which the subject positions one rod to the same apparent depth as two fixed rods at 5.59 meters. The problem of detection will be made more difficult by the fact that the video signals being returned are monochromatic. If a filter wheel were provided in front of the camera, a succession of pictures could be made that could be recombined in a ground facility into a color composite. Such a filter wheel might provide useful contrast enhancement even when viewed monochromatically in real time, enabling the operator to penetrate camouflage. The possibility of providing a standard color video camera could also be considered, but the lower resolution might underweigh any advantages the color would yield. Just as stereo is not a productive use of two video signals, full color is not a worthwhile use of three. How many different frequencies will be available for the radio communication link backup to the optical fiber? If there is only one, then only a single AROD can safely by flying within radio range of any control unit. If there are a number, then some means must be provided to change frequencies easily to match a control unit and AROD and to avoid any interference. Ideally, this should be possible for the vehicle in the air, so that any conflict that develops can be resolved. Otherwise, the frequencies would have to be carefully assigned from knowledge of what units were out in the field.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Tele Operated Vehicle (TOV) Advanced Electro-Optical Sensors Study, 16 October 1987

Author(s): Naval Weapons Center, Laser Systems Branch

OBJECTIVE:

This report looks at recently developed sensors which can outperform present sensors, reduce size and weight or otherwise improve the capabilities of the TOV to perform its reconnaissance and targeting missions.

APPROACH:

Discussion of Low-Light Level Television, Thermal Imaging Sensor, Laser Target Designator and Rangefinder, and a pointing/tracking system.

LESSONS LEARNED:

The present O/SM is configured with a pulnix 540TM solid state TV camera, a second generation image intensifier, and a Fujinon CIOX16A-SND zoom lens. It is recommended that the advanced system include a third generation image intensifier, and replace the zoom lens with a switchable two field of view optics system. The third generation intensifier should increase the responsivity in the near infrared by a factor of four, and increase resolution a minimum of 20%. An auto iris system to protect the intensifier from intense light sources should also be included. Approximate cost of this system in production should be $15K per unit. The present O/SM is configured with an AN/TAS-4 Night Sight. This system remoted weighs nearly 30 lbs, and has a closed cycle cooler which emits a significant audible noise. A recent U.S. Army development program for improved thermal imaging systems has resulted in the Thermal Weapon Sight. The Hughes Aircraft Division of General Motors has a version they claim is comparable in performance to the AN/TAS-4 at one quarter the weight and uses a quiet thermal electric cooling system. This sight is presently planned for use with individual and crew served weapons such as U.S. Marine Corps Modular Universal Laser Equipment (MULE) and the U.S. Army Stinger, M-60 and M-50 machine guns, as well as the MK-19 grenade launcher. The TWS is in full scale engineering development and projected unit costs are $10K. An eyesafe rangefinder would cost approximately $10K in production. A Lightweight Target Marker (LWTM) is estimated at $50K. A simple gyro stabilized pointing and tracking system with video tracker capability is estimated to cost $25K in production.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Additional Information on the LTM-86 Laser Designator, 8 February 1988

Author(s): Optic-Electronic Corporation

OBJECTIVE:

To provide a general overview on the features, characteristics, and performance criteria of the LTM-86.

APPROACH:

Included a laser systems comparison table, a discussion of test results from China Lake, and a copy of the operator's manual for the Compact Laser Designator (CLD), Model LTM-86.

LESSONS LEARNED:

The MULE has the following characteristics: weight - 38.5 lbs; designation distance (stationary target) - 3.5 km; designation distance (moving target) - 3 km; power required - 22-30 Vdc (< 190 watts); Transporting - 2 men; operation - 1 man. The GLLD has the following characteristics: weight - 61 lbs; designation distance (stationary target) - 9 km; designation distance (moving target) - 6.5 km; power required - 18-28 Vdc (< 375 watts); Transporting - 2 men; operation - 1 man. The LTM-86 has the following characteristics: weight - 14.95 lbs; designation distance (stationary target) - 3 km; designation distance (moving target) - 2 km; power required - 20-32 Vdc (< 200 watts); Transporting - 1 men; operation - 1 man. The LD-82 has the following characteristics: weight - 81.6 lbs; designation distance (stationary target) - Not Tested; designation distance (moving target) - Not Tested; power required - 18-32 Vdc (< 300 watts); Transporting - 2 men; operation - 1 man. Operational tests using the LTM-86 to designate targets for live laser guided ordnance have been successful. "Lock-on" of laser guided ordnance at slant ranges up to 90,000 feet (17.05 statute miles) has been accomplished with the LTM-86 designator 4 km from the target. Major user operational features have verified including first/last pulse logic, range performance from 150 meters to more than 8,520 meters, boresight, and operation with typical tri-service coded laser guided weaponry. Functions have been validated including multi-target indication, two target resolution, and single shot versus rep-rate designate and range read out performance. Ranging performance was validated over measured distances from a minimum of 150 meters out to a maximum of 8,520 meters (maximum available targeted distance).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV Masts, 23 May 1988

Author(s): Manuel Solorzano

OBJECTIVE:

To present possible mast alternatives.

APPROACH:

Discussion of identified mast alternatives.

LESSONS LEARNED:

We should try to avoid pneumatics and hydraulics, but not be absolute in rejecting them. Hydraulics can be driven with an electric motor on a hydraulic pump. For purposes of space utilization, the mast preferably should not cantilever. Variable height capability would be useful, but not a necessity. Maximum height has not been established, but the present 8 feet should be a minimum. Minimum height has not been established, but the instrumentation package should not exceed the weapons platform height. Stiffness in wind, especially wind gusts, is desirable only to a point, as the base vehicle will begin to react. Stiffness in rotation reaction to the pan axis torque load is at least as important. As far as cost, ease of integration, and minimization of engineering, the 5 stage hydraulic cylinder is recommended. This would be a cantilevered design for lowering the instrument pack below 3 feet. The hydraulic drive should be modified to have an electric motor drive the hydraulic motor. If the height is not critical, we could eliminate the cantilevering. Second recommendation would be a screw jack design.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Stressed Jack Lift, 1 June 1988

Author(s): Manuel R. Solorzano

OBJECTIVE:

Review of a proposed scissors type jack lift for the TOV mast requirement.

APPROACH:

Presented a description of the stressed lead-screw jack.

LESSONS LEARNED:

The double scissors lift designed by M. Solorzano has the following features: 1) Double and a quarter scissors design, 2) Inner scissors is milled 12" x 48" x 2" member. This combined with precision conical high torque bearings provide considerable lateral stiffness of the lift, 3) Outer scissors is 2" x 4" box member with high precision high torque conical bearings, 4) All members common 6061 aluminum, 5) Electrically driven 36" throw 1" diameter ball screw factory actuator ($900), 6) Two electrically failsafe ball screw detents (not motorized), 7) Simple leaf spring loaded stowing, 8) 8" to 120" variable height deployment (exclusive of sensor platform, 9) Provision to embed Pan mechanism in top elements, decreasing stowed profile, 10) Deliberate looseness in bearings to defeat inaccuracies in construction, seizing in position, 11) Stressed structure deployment to eliminate all positioning tolerances, 12) High torsional and flextural stiffness relative to instrument load, 13) bed requirement 16" x 48", 14) Approximate weight of lift, 80 pounds exclusive of base actuator, and 15) No cantilevering requirement. Unlike an industrial lift, the above scheme is extremely light, does not shift under a moderately heavy side load (a non-industrial requirement) and is equally zero-toleranced at any position. A less desirable but even simpler scheme is to eliminate the ball screw locks and drive up the lift until it rams into the stops of the payload plate. This would also be very rigid but would preload the platform upward; this would be the only zero-toleranced position. At any other height some slop could be expected. Since the actuator is bought as a factory unit, and the bearings are also factory items, only the baseplate, two center members, four outer members, and two cross braces need to be fabricated. The 4 mil tolerance requirement on 12" to 48" members (actually, only in bearing center mounting machining) is easily within competent machine operator effort.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Weapons Platform, TOV, 12 June 1988

Author(s): Manuel R. So!ɔ.zano

OBJECTIVE:

To discuss problems and solutions encountered in the development of the TOV's weapons platform.

APPROACH:

Discussed the harmonic drive, the weapons platform pan encoder, the weapons platform tilt encoder, the weapons tilt actuator, and the control station.

LESSONS LEARNED:

In addition to the harmonic drive being inadequate to the job, the coupling is badly engineered. Tension loading by the belt is centered on the drive sprocket, whose bearings are a plain bearing on one end (ok) and the gearmotor output bearing on the other (NOT ok). This unduly stresses the harmo: : drive in side loading, which will further ensure its early failure. There is no loading belt tensioner for the drive sprocket belt. As the belt stretches or the system wears, we will see the re-appearance of the slop, or mechanical hysteresis, which gave rise to the oscillations. The weapons platform pan encoder bears the entire belt tension of its drive belt. The weapons tilt encoder is loose or flexible in its mount. The reason for this is a loose belt. The extent of the looseness is about five (5) degrees. This apparently does not cause oscillations because the gun system is always preloaded (load unbalanced) downward. The weapons tilt actuator, a linear electric device, has about 0.1 inches of free travel, about a quarter of that in its end mountings. At a 5 inch pivot radius, this is about 4 degrees of error. Again, the poor mass distribution (unbalance) acts to eliminate this error IN STATIC POSITIONING. During firing, this is not the case. Hopefully during firing the system does not oscillate in position (slave) about the weapons tilt axis. Since 2 degrees of error is 10 feet at 100 yards and 60 feet at 600 yards distance, a ballistic computation using laser ranging is not worth doing unless these errors are reduced. This would involve: 1) adjustment of both weapons encoders, 2) measured tensioning of the weapons pan belt, 3) replacement of the tilt actuator with a preloaded ball or acme screw, and 4) tightening up the actual gun cradle, which is sloppy and flexible.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: New TOV Weapons Drive Recommendations, 18 June 1988

Author(s): Manuel Solorzano

OBJECTIVE:

To present recommendations for the TOV Weapons Drive.

APPROACH:

Discussed the tilt axis, pan axis, and recommendations.

LESSONS LEARNED:

Tilt axis: The tilt axis is used to elevate the weapon and to stow it in a rest with pneumatically actuated jaws. These jaws and the associated microswitch are extremely unreliable. They are also unnecessary. The Duff-Norton device is a very robust item, have 1,000 pound stall force and 2.7 inch/second max speed. It is also not backdrivable, being a lead screw device. Therefore it would make an excellent parking device itself. As a precision device for weapons training it needs better mounting, the present allowing +/- 2 degrees of motion with the weapon mounted. This has terrible implications for weapons training at longer ranges. Thus: replace the mechanical jaws with steel backed rubber V-block, eliminate the jaw structure, pneumatic actuator, associated air hoses, valves, associated sequencer functions, and add precision low tolerance mounts for the actuator. Pan axis: This drive system requires extensive redesign, beginning with the inertial loads, drive belt, drive cog, harmonic drive, and motor. Recommendations for the Pan axis: 1) major simplification of weapons control computer suite & software; 2) a more complete motion analysis of the entire weapons platform; 3) modification of the weapon mount. The present positioning causes minor disturbance torques to cause increasing rotation away from the firing angle; 4) study of the belt drive capacity; 5) redesign of the tension adjustment device. It is bending; 6) redesign of the drive cog to a fully bearing supported device. At present it is partly supported by the gearbox output shaft, placing an undue strain on an already inadequate device (shaft can actually be observed to deflect under moderate belt tension); 7) Addition of a flexible motor coupling (standard design); 8) change to a larger capacity gearbox of greater failure torque; 9) possible addition of an electric brake. This must slip before reaching the failure torque of the gearbox selected if not placed between the gearbox and the load; and 10) change to larger capacity motor, possibly the same Inland 2113/7 device retrofitted to the surveillance system.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: New TOV Surveillance Drive Recommendations, 18 June 1988
Author(s): Manuel Solorzano

OBJECTIVE:

To present recommendations for the TOV Surveillance Drive.

APPROACH:

Discussed the tilt axis, pan axis, and recommendations.

LESSONS LEARNED:

As it is now evident that the present surveillance pan and tilt drives are greatly underdesigned, the following are recommended rework: Tilt axis: As was warned in previous memos, holding torque in excess of 1.5 in-lb at the load would stress the present drives. It was discovered with the last motor damaged that the effective required holding torque was 60 inch-lb. This was equal to the maximum rated output capability of the motor/gear system, IGNORING ALL TRANSMISSION LOSSES. Actual motion torque requirements were in ADDITION to this. Since even with a perfectly balanced load we cannot guarantee that the load is not changed in the field (removal or addition of sensors, running the load up against tree branches, functioning on a vehicular grade, etc.) a superior scheme would require low holding torque and yet be as fast as required. This means an electric brake, a large motor/gearhead, or nonbackdriveable gear, such as a worm gear (inaccurate) or a lead screw. As a lead screw is being adopted for the follow-up version of this axis, retrofit of the same device is feasible and recommended. Using a IDC H105 series device with an 8 inch throw this device is rated: 14 inches/sec unloaded, 210 lbs force stall, 0.003 inches repeatability, low wear/low tolerance Teflon coated lead nut. Placing this device perpendicular to the tilt rotation axis, with a 3.5 inch moment arm this device will hold up to 800 lbs in place. Pan axis: No damage has been incurred on this motor drive system. However, should the vehicle be parked on a grade, resulting in a considerable holding torque requirement, or should an operator perform rapid motion control for a period in excess of 1 minute, damage is very likely. The best solution here is a direct replacement for the motor. The present motor has an armature thermal time constant of about 40 seconds. Adaptation of the Inland QT2113 motor gives a thermal time constant of about 9 minutes. The stall force of this motor is 300 inch-oz. This is much greater than the 20 inch-oz of the present motor. Run through the present 60:1 harmonic drive, it would generate 90 ft-pounds (1800 in-oz). In conjunction with a leadscrew for tilt, this would eliminate: all overload conditions, both position and operator induced; all unstowing software; all stowing pins, holes, etc.; all associated pneumatic hoses, valves, tanks; and most sequencer control requirements.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	Final Report for Analytic Support for Fire Support (Artillery) Robotics: Forward Observer Real-Time Teleoperator (FORT), 28 September 1988
Author(s):	Robert Finkelstein and James Taylor

OBJECTIVE:

The objective of this work was to: (1) recommend potentially suitable mobility platforms for a subsequent Proof Of Principle of FORT; (2) provide the basis for an O&O Plan for FORT; and (3) generate an interest, in the artillery community, to determine the ability of FOs to acquire targets using remotely operated sensor suites (including stationary ones).

APPROACH:

The analysis was limited a priori to: a teleoperated M113 vehicle (as would be used in the Fire Support Team (FIST) or the Elevated Target Acquisition System (ETAS) concept); a High Mobility Multi-Purpose Wheeled Vehicle (HMMWV, M998), as would be used in the Army's Tech-based Enhancement for Autonomous Machines (TEAM) program or the Marine Corps Tele-Operated Vehicle (TOV) program; a Teleoperated Mobile Anti-Armor Platform (TMAP) vehicle (as would be used in the TMAP) program); the AAI Corporation's High Mobility Multipurpose Articulated Vehicle (HMMAV). In addition to these platforms, a moveable (but non-mobile) sensor pod and an unmounted forward observer were included in the analysis. The number of platforms, while limited, seems to cover a suitable range of size, performance, and cost for potential near-term FO platforms.

LESSONS LEARNED:

It is not certain whether FORT should have laser designators onboard to illuminate targets for laser-guided weapons. Active emitters, like lasers, expose themselves to retaliatory fire, but the potential consequences are not as tragic with unmanned platforms as with an exposed FO. Laser designators, however, are very expensive, and platforms carrying them could not be considered expendable. Also, laser-guided munitions are likely to be replaced by teleoperated munitions (such as Fiber Optic Guided Missile (FOG-M), or autonomous munitions with smart seekers. FORT may not need to perform laser designation.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Mathematical Analysis of Scissor Lifts, June 1989

Author(s): H. M. Spackman

OBJECTIVE:

To derive general equations for calculating reaction forces throughout a scissor lift.

APPROACH:

Calculated the reaction forces in the lift, determined the correct placement for an actuator in the lift, and discussed strength and rigidity issues associated with the lift.

LESSONS LEARNED:

In order to derive these equations, two critical observations were made. The first observation was that the reaction forces in the scissor members outside of the levels containing the actuator are completely unaffected by the orientation of the actuator. This allows the scissor members above the actuator and the members below the actuator to be modelled as two "basic scissor structures," a scissor structure that is pinned to the ground at all four bottom joints and that contains no actuators. The second critical observation was that if the lift is assumed to be frictionless, then the principal of conservation of energy applies that states that work in equals work out. This principal allows the actuator forces to be calculated directly.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Minutes of 25 April 1991 - UGV, ISG Meeting, 16 May 1991

Author(s): Jed Dunbar

OBJECTIVE:

To define the types of payloads available to perform UAV missions.

APPROACH:

Discussion on sensor characteristics, FLIR analysis, radar analysis, Non-Communication Electronic Support Measures (NONCOM ESM), Homers, Non-Communication Electronic Countermeasures (NONCOM ECM), Communications Electronic Countermeasures (COM ECM), Decoys, Meteorological Intelligence systems, Radio Relay systems, and Laser Target Designator systems followed by Conclusions/Recommendations.

LESSONS LEARNED:

Definitions of Television (TV), Low Light Level Television (LLLTV), Infra-Red Linescanner (IRLS), Infra-Red Search and Track (IRST), Forward Looking Infra-Red (FLIR), Synthetic Aperture Radar (SAR), Moving Target Indicator (MTI) Radar, Communications Electronic Support Measures (COM ESM), Non-Communications Electronic Support Measures (NONCOM ESM), Communications Electronic Countermeasures (COM ECM), Non-Communications Electronic Countermeasures (NONCOM ECM), Electro-Optical Countermeasures (EOM), Decoy, Meteorological (MET), Radio Relay, Thermal, Magnetic Anomaly Detector (MAD), Active Sonar, Passive sonar, and target designation systems. Tables showing specifications for TV, LLLTV, IRTV, FLIR, and IRLS systems currently available were included. Several matrices were included which showed: 1) missions versus payloads, 2) applicable payloads versus mission payload requirements for individual missions, and 3) ground resolution/minimum scale requirements for imagery interpretation tasks.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Camera Stabilization, 30 May 1991

Author(s): Nelson A. Merritt

OBJECTIVE:

Presented a description of a method which can be used for stabilizing a camera on a moving platform.

APPROACH:

Discussion of the stabilization problem and two proposed solutions to the problem.

LESSONS LEARNED:

A camera mounted on a moving platform will pick up some or all of the platform perturbation, causing the camera picture to vibrate to the point where it is unusable. Some of the high frequency vibrations can be filtered out by the camera mounting, but low frequency excursions are more difficult to eliminate. The problem can be handled in either of two ways: 1) A stabilization mirror is installed in front of the camera lens and tilted at 45 degrees to the line of sight. The stabilization mirror is driven in the axis of vibration at one-half magnitude and opposite in phase to the vibration by an accelerometer and amplifier mounted on the moving platform. It is a low mass system and as such velocity and acceleration requirements are well within the state-of-the-art to effectively cancel out any vibration effects and present a stable scene to the viewer; 2) An alternative method concerns a camera which is already equipped with a motorized integral pan and tilt. A differential circuit is inserted in the line between the tilt motor and tilt control unit. An amplified accelerometer signal, opposite in phase, is connected to the remaining input to the differential. The accelerometer input effectively cancels out the vibration. Higher frequencies could be a problem with this method as this is a higher mass arrangement. However, it has been our experience that frequencies up to 12 to 14 hertz can be easily handled in a somewhat similar situation such as a tank gunners sight where scenes must be stabilized for firing on-the-move. Vibrations encountered in this case exceed the excursions found in the case of the moving camera. Lower frequencies, down to a fraction of a hertz are easily handled with rather simple circuitry.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A Real-Time Automatic Target Acquisition System

Author(s): Philip David, Stephen Balakirsky, and David Hillis

OBJECTIVE:

To describe a system which performs automatic target acquisition (ATA). ATA is the process of locating targets using data from one or more sensors. Although many types of targets may be considered and many types of sensors used, this paper focuses on the problem of detecting military ground targets using data from visible, infrared (FLIR), nonimaging, and range sensors, all of which are integrated on a robotic ground vehicle.

APPROACH:

Sections 2, 3, and 4 describe our image registration, target detection, and tracking algorithms, respectively. All of these algorithms have been simulated in software and have been run on real data; some have been implemented in real-time hardware. Section 5 describes how all of these algorithms will be implemented to run at a rate of 30 frames per second. In Section 6 we describe the future enhancements planned for our system. Finally, we conclude with a discussion of advances made by this ATA system.

LESSONS LEARNED:

The system currently requires targets to be moving before they can be acquired, but we believe that this is a small sacrifice for the performance increases obtained over previous stationary target ATA systems; there are numerous applications in which such a system would be ideally suited. Although the complete system has not been tested in a real battlefield environment, initial experiments are positive. We are currently implementing this system in real-time hardware and, when done, will perform extensive field tests and report on the results. A number of difficult problems have been addressed by this system: platform motion, dust, exhaust, cloud shadows, vegetation movement, low contrast targets, and a wide range of apparent target sizes. Problems which future systems must address are target acquisition on a moving vehicle, the acquisition of stationary targets, and target classification and recognition.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Features of the LTM-86

Author(s): KEI, A Subsidiary of Optic-Electronic Corporation

OBJECTIVE:

To present a description of the LTM-86 laser.

APPROACH:

Discussion of the laser transmitter, sighting optics, rangefinder module, range receiver, control box, power supply, dimensions, and specifications.

LESSONS LEARNED:

The Model LTM-86 Nd:YAG Laser is a target marker, a designator and a rangefinder. The laser transmitter is a modular box that is 4 x 5 x 12 inches and weighs approximately 7.5 pounds. The Nd:YAG laser is conductively and convectively cooled, eliminating the normal closed-cycle cooling system. Missions of 60 seconds duration at a rate of 10 pps may be conducted every two minutes. This is twice as long as necessary for most designation periods for conventional laser guided weapons. A separate sighting optics and rangefinder module is attached to the top of the laser transmitter. This provides range data which is displayed in the eyepiece to a maximum of 9,995 meters with a resolution of 5 meters. To permit discrimination between two or more targets in the field of view, the user can select either first- or last-target mode of operation. Targets as close together as 30 meters can be resolved. Minimum ranges of under 200 meters are possible. The range receiver and sighting optics are housed in a rectangular module that is approximately 2 x 5 x 12 inches. The range receiver/sighting optics module weighs approximately 2 pounds. The control box is 2 x 2 x 4 inches and weighs about 1/2 pound. Primary power for the LTM-86can be supplied by several combinations of battery packs using either rechargeable NiCad or Lithium batteries. If only the target marker/designator function is used, the entire space normally occupied by the range module is available for batteries. A simple rifle sighting telescope can be used for sighting and batteries capable of 60 minutes of operation are available in a box that weighs less than two pounds. The entire system with a lithium battery pack suitable for 60 minutes of missions weighs only 12 pounds and is 5 x 8 x 12 inches overall.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Response to Issues on the Tactical Unmanned Vehicle Operation and Performance

Author(s): Bill McLean

OBJECTIVE:

To provide information on unmanned vehicle operation and performance based on general knowledge of displays and sensor characteristics.

APPROACH:

Discussion on video resolution vs target detection and soldier characteristics affecting target acquisition and weapon alignment accuracy.

LESSONS LEARNED:

In general, an increase in system video resolution increases proportionally the range and probability of detection, or decreases the time to detection for a sensor whose field of view (FOV) is smaller than the area to be scanned. However, reduced visibility in the wavelengths of the sensor's response can change this proportional relationship. On a given situation, many identified factors can alter the range, probability, and time of detection, such as target contrast, size of the search field, complexity of the background, target masking and movement, training, etc. One model that was developed for predicting and comparing the performance of night vision imaging systems is called the "Johnson Criteria". This criteria determines the detection, orientation, recognition, and identification of a target by the number of imaging line pairs of the sensor/display across the minimum or critical target dimension. A German modification of the Johnson Criteria reports both 50 and 90 percentile probabilities (BOHM, 1985). For detection at the 50% level this value is 1 line pair (two lines) per minimal dimension, and 1.8 line pairs for the 90% level. For identification, the number of line pairs for 50% and 90% are 7 and 12.5 respectively. Therefore, the basic Johnson Criteria assumes a proportional relationship between video resolution and target detection/identification performance. Because of the number of additional known variables besides size that can affect the time and probability of target detection (which the Johnson Criteria does not include), the Johnson Criteria is useful more as a tool to compare electro-optical systems in a relative way than to predict absolute times and probabilities of detection.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

DATALINK

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Over-The-Flange Payout Tests, 10 November 1986

Author(s): A. Nobunaga

OBJECTIVE:

The purpose of the over-the-flange payout tests were to determine the geometrical limitations to that payout concept with respect to cable binding during payout.

APPROACH:

Discussion of background material, test procedures, test results, and conclusions

LESSONS LEARNED:

There is a payout "window" through which the cable will not bind during payout. the same size guide can be used for either the 15 or 20 inch diameter flanges provided the guide is mounted 20 and 30 inches, respectively, away from the flange. This would not affect the overall dimensions of the payout system because the sum of the length of spool and distance to guide would be the same for both cases. Therefore, no special hardware would have to be built to accommodate either payout spool which still allows flexibility in payout concepts. Because similar loops were formed during payout over different diameter flanges, it seems that it is independent of flange diameter. However, per reference (a), it was learned that loop formation is a function of payout speed. The slower the speed, the larger the loop formed. Therefore, although it seems like the flange will not interfere with cable payout, as the payout speeds increase, the flange will have a definite effect on payout. Further, the formation of loops adds another payout parameter which must be considered. The loops can hit and bind on other payout spools as well as any hardware or other cable within the payout system. Therefore, if payout over-the-flange is to be continued, more testing is required to determine the effect of payout speed on loop formation and cable binding. The use of tapered flange or no flange on the payout end of the spool may solve these problems.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Status/Progress as of 26 May 1987

Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present the current status of the fiber optic system.

APPROACH:

Discussion of spools, testing, winding, guide, frame, pack, recovery, and problems.

LESSONS LEARNED:

Used cable recovery winder to payout 2700 meters of Vector hytrel cable on 4 May 1987. 8 km/hr payout speed achieved. One 2350 meter pack wound with 100% conformal coating coverage -- completed 26 May 1987. A 1650 meter pack will be wound with conformal coating applied in strips 90 degrees apart -- estimated completion 28 May 1987. Present cable winding system able to wind 300 m/hr with 100% adhesive application. Adhesive application seen as major time constraint. Will begin winding with strip application of adhesive with 1650 meter length of Vector CL-139 cable. Interest in testing twine winding. Need to develop high helix angle level wind system. Determine whether adhesive required. Abandoned winder design using Army RL-31 frame. When mounted on HMMWV, it would require two men on the vehicle to pass the cable down to two men on the ground. Need for a lower profile winder required. Present winding system too slow. Adhesive application seen as major constraint to winding speed. Will try strip adhesive application and possibly twine winding to speed up winding process. There have been cases where OFTI connectors do not fit on the fiber in the Vector hytrel cable. The hole size in the connector does not accommodate Sumitomo fiber. Possible problem seen with Vector polyurethane cable. Had difficulty switching recovery system to DC power. 20 amp current rating of motor seen as a problem -- standard switches are rated to 10 amps maximum. Will use a 10 amp switch to activate a 25 amp relay to run motor. Switches, relays, and circuit breakers on order. Need to fabricate and wire components together.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Robotic Combat Vehicle System Study, July 1987

Author(s): B. C. Caskey and E. R. Hoover

OBJECTIVE:

To address the use of robotic combat vehicles for anti-armor and reconnaissance missions for the U.S. Army.

APPROACH:

Description of mission requirements and assessment of current underlying technologies. Description of the operating characteristics of the near-term robotic combat vehicle based on the limitations and capabilities associated with current and near-term technology. Discussion of program plans for near-term engineering development, mid-term applied development, and far-term basic research and development.

LESSONS LEARNED:

Near-term technology will only support defensive and reconnaissance type missions. Near-term vehicles will be simple, small, lightweight, easy to operate, and inexpensive vehicles with target acquisition and weapon systems. Communication systems will have secure transmission links, high bandwidth, low probability of intercept, and longer range. Control systems will have improved capabilities for high speed movement over more difficult terrain.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Random Wind Payout Test, 24 July 1987

Author(s): A. Nobunaga

OBJECTIVE:

The purpose of this test was to determine whether cable that was random wound with an adhesive could be successfully deployed.

APPROACH:

Discussion of the winding procedure and the results of the payout test that followed.

LESSONS LEARNED:

Random winding requires little winding time and effort to form a cable payout pack because any winding flaws are not corrected. Mechanically, the payout looked smooth and clear until the vehicle reached 35 mph. At this point there appeared to be a multiple loop payout and then the remaining cable pack with approximately three layers was pulled out at once and the cable broke at a termination point on the frame, which is used to prevent the datalink electronics from being pulled out. There are several possible causes of the multiple layer or loop payout. The first cause is too much adhesive. There may have been a place on the payout pack where the adhesive force overcame the forces holding the cable in the payout pack. The adhesive is used to facilitate cable pack handling and it prevents the cable pack from separating while it is mounted on the payout hardware. The adhesive could be diluted in future tests to weaken the holding forces on the cable. Another cause of the multiple loop or layer payout could be the random winding. Because the cable is random wound, the cable during winding could leave large gaps in the layer where the adhesive could build up. The buildup of adhesive as mentioned before could have caused adjacent layers to hold together too strong. Further, the random winding could allow the cable to double back on itself. The doubling back of cable could cause tangling during payout or multiple loop payout. It appears that random winding with an adhesive is not feasible because of two factors, adhesive buildup and doubling back of cable during winding. It appears that the doubling back of the cable caused multiple loop payout whereas too much adhesive caused multiple layer payout. To determine which factor has a greater affect would require random winding of cable without an adhesive and random winding with different dilutions of the adhesive.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Technology Assessment for Communication Links for Mobile Users in a Hostile Environment, 1987

Author(s): Communications and Electronics Command

OBJECTIVE:

To address the major problems associated with the real time transfer of low and high bandwidth analog and digital signals in a scenario where at least one end of the link is constituted by a mobile user operating in an unfriendly environment.

APPROACH:

Discussion of possible constraints on a communication link located in a possibly hostile environment, the advantages and shortcomings of analog versus digital, communication configurations, bandwidth requirements, range considerations, antennas, secure communication issues, jamming considerations, and proposed links for mobile users in a hostile environment.

LESSONS LEARNED:

At the present time the following can be stated with reasonable accuracy: 1) a fiber optic communication link could probably be deployed within one year, 2) a conventional RF link (non secure) could also be deployed within the same time frame, 3) an RF link with secure data transmission (for example, using a frequency hopping system) and non secure video (at most analogically scrambled) could be implemented in a two - three year period, 4) given intense research and technological improvements, a fully digitized, direct spreading spread spectrum video system could be available within 5 - 10 years, 5) for distances greater than 3 - 10 km drone support will be necessary, and 6) more research is needed to study the feasibility of using near optical (ultraviolet, infrared, etc.) wavelengths and laser or particle beam systems for communication purposes. Finally, it must be realized that none of the systems available on the market can be readily applied toward the communication links described above (some modification would be necessary in every case). Therefore, a price list is not given. It is expected, however, that the price range will be between tens of thousands and hundreds of thousands of dollars, according to the complexity and sophistication of the systems.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Image Compression Technology and Techniques, April 1988

Author(s): Tsai-Hong Hong, Marilyn Nashman, and Karen Chaconas

OBJECTIVE:

To report the state of image compression technology, to describe image compression techniques, and to select algorithms which can be implemented on parallel image processing hardware for the purpose of remote driving.

APPROACH:

Discussion of techniques used to measure the fidelity of reconstructed images with both subjective and objective criteria, first generation data compression schemes, second generation data compression schemes, the transmission of video images at very low data rates, and advances in digital coding of real-time applications for low bandwidth transmission.

LESSONS LEARNED:

Data compression methods should provide a compression ratio of 4000:1 as well as a reconstructed image that can be used to operate a vehicle under variable lighting conditions and over varied terrain.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Concerns Regarding Cable Handling Tasks, 12 July 1988

Author(s): A. Nobunaga

OBJECTIVE:

This memo will present concerns that I have regarding the cable handling task for the TOV project.

APPROACH:

Two areas will be discussed -- cable recovery and the rapid winder system.

LESSONS LEARNED:

It was requested in a TOV review meeting that the cable recovery system by modified to allow one man operation. This can be accomplished by moving the controls from the recovery winder frame to an area near the driver. Although the speed controls for the winder can be moved, there should still be a person in the HMMWV bed monitoring the recovery operation. This person would be responsible for notifying the driver/operator of any problems with the winder subsystems, such as a clogged cable cleaning system. Furthermore, when TOV starts using the 10 km lengths of cable, it will be necessary to use two people to unload the winder and put a new spool on. There are two approaches that can be used to attain the goal of one man operation. Controlling the speed of the winder can be done electronically or mechanically. Both methods would require, however, an electric brake on the winder spool. Because of the built up inertia in the spool as more cable is recovered, the spool does not stop spinning when the power to the motor is cut. The electric brake would replace the operator, who presently grabs the flange to stop the spool. Therefore, an electric brake needs to be procured and mounted onto the recovery vehicle. Electric speed control of the winder can be accomplished by installing a voltage regulator to the system. The speed of the winder would then be proportional to the voltage the motor sees. This would be the ideal solution to the task -- NOSC winders use this type of speed control. From an operator standpoint, it would be desirable to have a cable length counter added and a better way to load and unload the spools. A hand crank should be added to the end of the ball reverser unit to assist winding startup.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Low Data Rate Remote Vehicle Driving, August 1988

Author(s): Martin Herman, Karen Chaconas, Marilyn Nashman, and Tsai-Hong Hong

OBJECTIVE:

To present video compression techniques for use in low data rate remote vehicle driving.

APPROACH:

Discussion of problems associated with remote vehicle driving and description of several video compression algorithms currently implemented on PIPE.

LESSONS LEARNED:

When driving in cross-country terrain using either full video or compressed video the driver found it difficult to determine global relative vehicle location, determine the orientation of local ground surfaces, distinguish ditches, gullies, and other obstacles, and determine the range of objects from the vehicle. It appears that transmitting images at a rate of a few per second and then providing realistic video simulation to the operator may be most effective way to perform video compression.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Robotic Vehicle Communications Interoperability, August 1988

Author(s): Daniele Mariani

OBJECTIVE:

The primary goal was to propose a communications interface standard, consisting of a set of protocols and a unique message format, that will lead to communications interoperability.

APPROACH:

Discussion on Interoperability, Robotic Vehicle System Functions, and Representation of the Compiled Information, Protocol Testing.

LESSONS LEARNED:

Digital advantages: 1) good performance is possible with a signal-to-noise ratio of only 20 to 30 decibels (dB). A frequency-modulated analog system would require 30-40 dB for similar quality, and an amplitude-modulated analog signal an even higher signal-to-noise ratio; 2) works well with systems requiring the data relayed over multiple hops, because the digital information is regenerated at each relay. This is in contrast to an analog system, where the noise and distortions are not simply those of the weakest link, but those of the accumulation of all the relays; 3) error control techniques can be used to detect and/or correct most bit errors; 4) most encryption techniques are discrete in nature, allowing for data security; 5) transparent to the type of data. The signal could be voice, video, or computer data and any user with a compatible digital interface could receive the information. For analog systems, channels must be modeled according to the nature of the signal; 6) a higher capacity per carrier frequency can be accommodated, using time division multiple access (TDMA) technique. TDMA is a more efficient multiplexing technique than frequency division multiplexing (FDM), which is used with analog systems. Most sensors have an analog output. To use a digital system, an analog-to-digital (A/D) conversion must take place. This process increases system complexity and cost. It also can introduce quantization error.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Bending Attenuation Testing of Dispersion Shifted Fiber Cables, 22 August 1988

Author(s): A. Nobunaga

OBJECTIVE:

To present the results of bending attenuation tests performed on Optical Cable Corp (OCC) and AT&T cables.

APPROACH:

Discussion of cable construction, bending tests, and results.

LESSONS LEARNED:

Operational testing of the existing TOV single-mode fiber optic cable has shown that there is a marked increase in attenuation when the TOV runs over the cable. To solve this problem, "off-the-shelf" dispersion-shifter single-mode fiber optic cables were procured. A comparison of cables shows that the AT&T has the most kevlar -- 4,000 filaments vs 2,136 for TOV and OCC, and 3,204 for the Air Layable. Because the AT&T has a thicker jacket than either the TOV or OCC and it has the most kevlar, it should also have desirable impact and crush resistance. The OCC cable and Corning fiber do not perform as well as the AT&T cable and fiber. Further, from the AT&T data, the cabling process does not affect the performance of the optical fiber. From the bending attenuation data it appears that the AT&T cable performs well and could be a solution to the TOV cable bending loss problem. Further testing can be performed to determine whether the AT&T cable meets the remaining TOV cable requirements.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Video Compression for Remote Vehicle Driving, 1988

Author(s): Martin Herman, Karen Chaconas, Marilyn Nashman, and Tsai-Hong Hong

OBJECTIVE:

To discuss the remote vehicle driving problem and describe several video compression algorithms that have been implemented on PIPE, a real-time pipelined image processing machine. The paper then discusses how these algorithms are evaluated on real-world remote driving tests.

APPROACH:

The approach to the problem of video compression for remote driv to use a hybrid method which combines image processing techniques (i.e., techniques whose input is an image and whose output is a compressed image), transform techniques (such as the discrete cosine transform), and temporal frame reduction (i.e., transmitting fewer than 30 images per second).

LESSONS LEARNED:

Full rate video transmission from the vehicle to the operator requires about 60 megabits/sec for 512 x 512 images with 8 bits/pixel at 30 frames/sec. Wide bandwidth radio communication requires direct line of sight between the transmitter and receiver. This is not feasible in realistic outdoor scenarios where vehicles are likely to be driven behind hills and mountains and therefore hidden from direct view by the operator station. Wide bandwidth links are also relatively expensive. Further, even is such a link were available, full rate video would use up a large part of the bandwidth allocations. Fiber optic links, which have wide bandwidth communications capabilities, also have several problems, including limited ruggedness, difficulties in deployment and retrieval, and the problem of repairs. Many of these difficulties can be overcome by utilizing narrow band radio links which have communication bandwidths on the order of 100 kilobits/second. The color camera used for the test obtained 512 x 512 pixel images with 8 bits each of red, green, and blue. The camera had a 90 degree field of view. Problems encountered during the test were: 1) global vehicle location relative to the background and landmarks was very difficult to determine, 2) the slope of the local terrain was very difficult to determine, 3) ditches, gullies, rocks, and other obstacles were difficult to distinguish, and 4) range from the vehicle to objects and terrain features were difficult to determine. It seemed important to be able to see a portion of the front of the vehicle in the image.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Land Vehicle Teleoperation Under Conditions of Reduced Video Resolution, August 1989

Author(s): J. L. Schoeneman and D. E. McGovern

OBJECTIVE:

This experiment was designed to evaluate the capability of a human operator to teleoperate a vehicle with varying levels of spatial and temporal bandwidth reductions on the video feedback signal.

APPROACH:

Two separate tests were conducted: 1) Driving simulation in which subjects were asked to review prerecorded driving tapes under varying conditions of video resolution. The terrain conditions were also varied and consisted of a moto-cross track, open mesa, and a high-speed highway. 2) Subjects teleoperated a small remotely controlled vehicle over a short serpentine course with "gates". Time to complete each course under varying conditions was the primary performance measurement.

LESSONS LEARNED:

In the driving simulation condition, there was general agreement among subjects that reducing bandwidth to 500 kHz would result in very marginal estimated capability to teleoperate the vehicle, and most felt that 250 kHz provided a video picture which did not allow consistent, effective vehicle teleoperation. The subjects in the teleoperation condition found that bandwidths lower than 125 kHz were technically achievable, but in general did not allow consistent, effective vehicle teleoperation. The time on the course increased as the bandwidth decreased. The major finding was that vehicle teleoperation can be performed with significantly degraded video quality. The method of temporal resolution reduction used here is not identical to what would be experienced in a field system. A field system causes a time delay between what the vehicle is seeing and what is presented to the operator. The magnitude of the effect of a time delay on performance requires further testing. This experiment provided useful suggestions for additional testing, such as using more realistic terrain or training.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Cable Handling Design Review Minutes, 9 January 1989

Author(s): A. Nobunaga and A. Nakagawa

OBJECTIVE:

To present the current 3 km capacity outside payout design.

APPROACH:

Discussion of two outside payout over-the-flange designs: one with a freely rotating flange and the other with a 45 degree tapered insert on one end.

LESSONS LEARNED:

The payout system delivered to NOSC SD was a combination of the two designs considered: aluminum spool, 12.75 inch diameter mandrel, 12 inches long, 18.5 inch diameter flanges, 1 inch thick 45 degree tapered nylon spacer, and a 20.62 inch outside diameter (OD) rotating flange (3 km capacity).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Test Reports, 12 March 1989

Author(s): G. S. Hall

OBJECTIVE:

To present status reports on the TOV system.

APPROACH:

Discussion of problems encountered during testing of the TOV #1 and TOV #2 and the actions taken to resolve each problem.

LESSONS LEARNED:

Comparison testing was done using the Westinghouse (green/black) CRT's and the Sony (black/white) CRTs. The operators seem to prefer the Sony for normal driving, but like the high resolution of the Westinghouse for surveillance with the mobility head. The cable is highly vulnerable. Once, photographers tripped over the cable, breaking the optic link. Twice, the spool ran out of cable, parting it. Once, the mud-flap caught a previously laid piece of cable, parting it. Once, the payout system bound, parting the cable. A cable level indicator is required. Although running out of cable occurred only twice, this is the largest single cause of cable destruction. Missions are being shortened because of this problem; a fourth to a third of driving time is dedicated to expending unused cable without parting it. It was discovered that, with minimum practice, operators could hold the surveillance optics on targets moving about 55 mph at a closest point of about 100 meters. There is currently no provision for repair or replacement of broken cable during a mission. Lt. Col Harper considers it a priority to obtain a splicer, capable of making quick field repairs in the event of a break during the demo. A review of all data collected (ref. Test Status Reports for 2 Feb. - 1 Mar. 89 and 2 - 12 Mar. 89) indicates that the stringency of requirements for a production vehicle, coupled with effective crew training should produce a highly reliable system. Expanding the scope of the system to include a field expedient repair system should produce a very usable system.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle (UGV) Frequency Supportability/EMC, Letter Report, 31 January 1990

Author(s): T. Grove and V. Denny

OBJECTIVE:

In a series of meetings with the Unmanned Ground Vehicle Joint Program Office (UGV-JPO) ECAC was tasked to perform certain tasks related to frequency supportability and electromagnetic compatibility (EMC) for the UGV. Specifically, Task 1 charges ECAC to determine the frequency supportability/EMC issues associated with the deployment of video data links using: a) the SINCGARS-V radio and, b) the 1710-1850 MHz band. A second task was to have ECAC provide consulting support to the UGV-JPO. This report addresses Task 1.

APPROACH:

Discussion of SINCGARS Frequency Supportability, ECAC SINCGARS Reports, and Power Coverage Plots (SINCGARS). In addition, discussions of 1710-1850 MHz Band Frequency Supportability and Power Coverage Plots (TMAP).

LESSONS LEARNED:

Links distances of 30 km can be achieved using the SINCGARS radios; however, in cosite situations, studies indicate that link distances are drastically reduced as the number of cosited SINCGARS radios in use increases. Both the SINCGARS (30-88 MHz) and the 1710-1850 MHz bands are very congested and promise to become even more so in the future. Frequency support at selected sites in either of the two bands for limited UGV testing could probably be achieved. Frequency assignments for the UGV tests would likely be on a non-interference, unprotected basis. Long term, worldwide frequency support for an operational UGV system, even with video compression technology, does not appear feasible in either of the two bands. The UGV-JPO should attempt to better define the frequency requirements of the UGV in terms of emission bandwidths and estimated number of channels required for UGV systems in an operational environment. Further, system architecture should be examined regarding the practicality and technological feasibility of using repeaters for non-line-of-sight links. Upon completion of the above, the UGV-JPO should commission a study to explore frequency bands that could adequately support the UGV in an operational environment. If pursuit of the SINCGARS as a solution to the UGV communications needs is continued, consideration should be given to having vehicular cosite studies performed.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Surrogate Teleoperated Vehicle (STV), 8 May 1990

Author(s): Naval Ocean Systems Center

OBJECTIVE:

The objective of the Surrogate Teleoperated Vehicle project is to develop Unmanned Ground Vehicle systems for delivery to Marine Corps and Army personnel in support of the following UGV program objectives: 1) Provide military personnel with UGV field experience; 2) Develop requirements to support UGV Full Scale Development; 3) Support Early User Test and Evaluation (EUT&E) of UGV systems; and 4) Develop concepts of employment.

APPROACH:

This document includes project objectives, technical approach, schedule, and cost estimates.

LESSONS LEARNED:

The STV data link will provide the means for information transfer between the Controller and RP. Included within this definition will be equipment to conduct optical and radio frequency (RF) data exchange. Optical data link components will include the fiber optic cable, a cable handling system, the electro-optics module, and a processor system. RF data will be passed through an RF data link. The Controller to RP link will be defined as the Command link since most of the information passed in this direction is used to alter RP equipment functional modes or actuators. Similarly, the RP to Controller link will be defined as the Instrumentation link since this data consists primarily of informative data feedback. The instrumentation link will transmit two video channels, two audio channels, and several serial data channels through a fiber optic cable. Digital time division multiplexing (TDM) will be employed to combine pulse code modulated (PCM) signals into a single high data rate serial stream. Optical wavelength division multiplexing (WDM) of long wavelength lasers will be used to provide simultaneous two way transmission through one low loss, single mode optical fiber. Optional means of bidirectional data flow using a single wavelength will be investigated. The STV RF link will be an alternate mode of communication, and will be used in the event of optical fiber or electro-optics failure. This mode of operation will be degraded in terms of less robust, RF data transmission paths, reduced data handling capacity, and, increased noise and error rates.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Compression Technology for AUVS Video Transmission, 30 July - 1 August 1990

Author(s): Richard A. Schaphorst

OBJECTIVE:

To describe three advanced compression techniques (Discrete Cosine Transform, Vector Quantization, and Bit Plane Coding) and compare their complexity and compression performance with the basic Differential PCM coding and Variable Length coding (DPCM/VLC) approach.

APPROACH:

Presented discussion on a system overview, image compression techniques, signal conditioning, signal processing, transform coding, bit plane coding, quantization, vector quantization, variable length coding, and test results.

LESSONS LEARNED:

DPCM/VLC performance is superior to the STANAG 5000 technique. The Discrete Cosine Transform (DCT) and Vector Quantization (VQ) algorithms provide a higher level of compression than DCPM for the same picture quality, but the implementation technology for DPCM is more mature.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: UGV Tech Base Comms Cable Handling, 28 August 1990

Author(s): Naval Ocean Systems Center

OBJECTIVE:

The objective of this task is to investigate the feasibility of developing two fiber optic cable handling systems for an Unmanned Ground Vehicle (UGV) system - one to support training scenarios and another for combat scenarios

APPROACH:

The approach in developing a combination cable payout/retrieval system will be as follows: 1) Define requirements; 2) Conduct market survey to investigate past & present technology; 3) Assess possible methods of employment; 4) Design system; 5) Procure hardware; 6) Fabricate and test system; and 7) Deliver documentation package that satisfies long term requirements of a 50 km system.

LESSONS LEARNED:

The training system would be capable of paying out and retrieving fiber optic cable from a single vehicle. Cost, logistics, and training-field maintenance make it desirable to perform both these operations from a stand-alone unit, while remaining on the same vehicle for both applications. The combat cable handling system would consist of a passive payout system on the remote vehicle and a cable recovery system on a separate vehicle to retrieve and rewind cable. During a combat mission, a prespooled cable pack would allow free cable payout; and after the mission, a recovery winder/vehicle would retrieve the reusable cable. Requirements: Distance/length - 1 km (Training), 30 km (Combat); Payout speed - 0-60 mph; Retrieval/Rewind speed - 30 mph (max.); Attenuation - Average loss of 1 dB; Power - 24 vdc; Human factors - Cable handling system set-up in 5 minutes; Reliability - Cable handling 99% reliable.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: OPTELECOM Cable Handling System Test Results, 4 September 1990

Author(s): A. Koyamatsu

OBJECTIVE:

This memo summarizes the work/repairs and tests performed on the Optelecom Fiber Optic Cable Handling System (FOCHS I), which was purchased by the GATERS program in 1986. The system has been in storage since 1987 after numerous operational failures. The objective of this task was to repair the system and determine its operational limitations and capabilities.

APPROACH:

Prior to starting the task, Jim Clark of Optelecom was contacted to obtain further information on the system he designed. According to Jim, the FOCHS I originally was designed for a 1.5 mm diameter fiber optic cable; however, he believed our AT&T 2.5 mm cable could be used with the system. To adapt the 2.5 mm cable, a 4.5 to 5 mm pitch is required to assure proper winding/unwinding. According to Jim, the system was rated to operate at 35 mph, using 24 Vdc power. He also mentioned that Optelecom's newer FOCHS I has improved pulley guides to prevent the cable from "jumping off" the pulleys and has a more responsive electronics system to keep up with payout and retrieval demands.

LESSONS LEARNED:

The system was made operational after installing two fuses and applying 24 Vdc power to the winder with batteries. The system also includes a servo control electronics box, which is mounted adjacent to the winder, and a payout mast to raise the cable above the vehicle it is mounted to. In conclusion, it is possible to use the 2.5 mm AT&T fiber optic cable with the Optelecom FOCHS I system. The storage capacity is 1 km and maximum operating speed is 15 mph (with a possibility of 20 mph). Location of the payout mast should be near center of vehicle to prevent cable from coming in contact with edges of vehicle. It is recommended that the FOCHS I system be used with the TOV #3 system. I am considering using it for STV controller controls testing.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: UGV Cable Survivability Analysis Technical Report, 12 October 1990

Author(s): Science Applications International Corporation

OBJECTIVE:

This report covers the UGV cable survivability requirements analysis, including the topics discussed at the recent Preliminary Design Review (PDR) Meeting held at Naval Ocean Systems Center (NOSC).

APPROACH:

A summary of optical, mechanical, operational, and environmental requirements for the UGV cable is given, along with discussion and analysis of how particular operational requirements affect the cable design and performance parameters. Cable development guidelines are given for the design, analysis, and manufacture of small diameter fiber optic cables. A discussion of specific tests for evaluating whether cable performance meets the UGV cable requirements is also provided.

LESSONS LEARNED:

The optical fiber should be buffered to about 900-950 microns in order to provide consistent optical performance within the cable structure. The added buffer should be a hard material, for example HYTREL 7246 versus the softer HYTREL 5556. The prevention of fiber break in the cable during vehicle runover is augmented by using optical fiber with a relatively high proof strain ($\geq$ 2%), and by insuring that the optical fiber can move or 'slip' axially within the cable structure to relieve excessive strain that develops on segments trapped beneath the vehicle tracks or treads. The use of KEVLAR (higher break strength cable) does not help significantly within any reasonable overall cable diameter constraint (for example, 2.7 mm max OD). For a KEVLAR cable with the latter diameter constraint, a reasonable breaking strength range is 100 to 200 lb-f. Cable performance under conventional (flat plate) crush, and abrasion resistance of the UGV cable are not important indicators of cable viability for the UGV system. The bend loss resistance of the cable can be improved by using "bend resistant" fiber as developed by NOSC-Hawaii Lab in conjunction with Corning Glass or others. However, the dispersion-shifted fiber presently used probably has enough bend loss resistance for the application. If optical fibers containing splices are used in the UGV cable, they should be true "high-strength" splices ($\geq$ 200 kpsi min, 250-300 kpsi nominal).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Vehicle-Command Center Communications in a Robotic Vehicle System, October 1990

Author(s): Harry A. Scott

OBJECTIVE:

To describe communication system requirement. for real-time control of multiple land vehicles.

APPROACH:

Review aspects of NIST real-time control system (RCS) architecture which apply to the design of a vehicle-command center communications link. Discussion of the communications link itself, specifically, addressing issues of data content, performance, communications architecture, and standards.

LESSONS LEARNED:

With the use of NIST real-time control system architecture coupled with high performance available products it appears possible to develop a well-structured, extensible, and fully functional vehicle-command center communications link.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV 500 Mbit/s Bidirectional Telemetry System, 22 January 1991

Author(s): Lloyd Yano

OBJECTIVE:

To present a description of the STV telemetry system.

APPROACH:

Discussion of the vehicle to control station data link, control station to vehicle data link, and major advantages of this system over the TOV system.

LESSONS LEARNED:

The vehicle to control station data link utilizes gallium-arsenide circuitry and operate at a serial baud rate of 500 Mbit/s. This link supports two digitized 8-bit video channels at 10 Megasamples/s, two digitized 12-bit audio channels at 52 Ksamples/s and four serial data channels of up to 38.4 Kbaud each. The control station to vehicle data link operates at a serial baud rate of 125 Mbit/s and consists of one delta-modulated audio channel running at a sample rate of 1.5 Msamples/s and seven serial data channels of up to 38.4 Kbaud each. The system electro-optics consists of 1.3 and 1.55 micron semiconductor lasers for optical transmission of the serial data through a single mode dispersion shifter fiber optic cable. Dichroic filter wavelength-division-multiplexers (WDMs) are used to optically duplex the two different wavelength signals onto a single fiber. Pinfet receivers are used to convert the optical signals to electrical signals. Optical dynamic range of the control station to vehicle link is 20 dB at 1.3 um, maximum sensitivity is -29 dBm (1 uW). Optical dynamic range of the vehicle to control station link is 17 dB at 1.55 um, maximum sensitivity is -23 dBm (4 uW). The major advantages of this system over the TOV system are the reductions in size and power consumption. Control station board count is 4 as compared to 13 in the TOV telemetry system and power consumption is approximately 6 watts as compared to 20 watts for the TOV system.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Tactical Unmanned Ground Vehicle Technology Review, 20 February 1991

Author(s): M. W. Miller, R. N. Seitz, and D. L. Wyatt

OBJECTIVE:

To describe the technology requirements for the TUGV program, compare these requirements with current technological capabilities, and suggest research programs which will successfully field a TUGV in the allotted time frame.

APPROACH:

Discussion of autonomous and teleoperated vehicles, human factor problems, MBUs, RSTA, OCUs, and communication systems.

LESSONS LEARNED:

Recommendations include RF backup link, development of single MBU control, testing of the Picturetel 4000 and Videotel video image compression hardware, identification of available FLIRS and image intensifiers, and the use of an inclinometer in the UGV.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV Command Telemetry Link Technical Specifications, 26 March 1991

Author(s): Robotic Systems Technology, Inc.

OBJECTIVE:

To present a discussion of the STV telemetry data links.

APPROACH:

Discussion of the STV command telemetry link and the STV Wideband Telemetry Link.

LESSONS LEARNED:

A 9600 Baud Full Duplex data link between the Operator Control Unit (OCU) and the STV vehicle is required to pass command data to the vehicle and status back from the vehicle. The system will be capable of transmitting and receiving data over a 4 kilometer distance. There will be a maximum of 14 systems in operation in a given area. The frequency pairs will be spaced on 50 kilohertz channels and the transmit and receive frequencies will have a 6 MHz split (5 MHz minimum). Each system will have a duplexer at each end. The duplexers will be as small and lightweight as practical, particularly the OCU unit. The FDX units must not generate any spurious radiation that would cause interference to other systems on the STV and OCU. Two wideband video transmitters will be located on a remotely controlled vehicle. The system will be capable of transmitting two full color signals with audio over a minimum distance of 4 kilometers to wideband receivers located at the Operator Control Unit (OCU). There will be a maximum of 14 systems in operation in a given area. The frequency pairs chosen for any vehicle will be spaced as far as practical, with no spacing closer than 50 MHz on a given vehicle. In addition, a full duplex data link operation in the 142-149 MHz frequency band will be operational on each vehicle. The wideband links shall not generate spurious radiation that would interfere with this link. The full duplex links will utilize narrow band (20 KHz) commercial equipment with vertically polarized antennas. An additional voice receiver (on 148.95 MHz) will be located on each vehicle for one-way voice operation from the OCU. All STVs will utilize the same voice channel.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Advanced Technology Vehicle (ATV) Testbed, White Paper, March 1991

Author(s): Kathy Dugas Garcia and Wendell Chun

OBJECTIVE:

To present a description of a self-contained, mobile UGV testbed being developed by Martin Marietta.

APPROACH:

The report was broken up into the following sections: 1) Introduction, 2) Testbed Research Applications, 3) ATV Testbed Description, 4) Martin Marietta Resources, and 5) Summary.

LESSONS LEARNED:

The RF system consists of four subsystems: 1) a very-high frequency (VHF) voice/tone subsystem, 2) an ultra-high frequency (UHF) remote control system, 3) an L-band video subsystem, and 4) an S-band data subsystem. The VHF voice/tone subsystem consists of a General Electric MVP mobile transceiver that allows for communications between the remote control site, the HMMWV, and field personnel/chase vehicle. The UHF Remote Control Subsystem consists of a transmitter/receiver pair. This transmitter control unit will be used by field personnel to status and override several levels of vehicle control for safety purposes. The L-band Video Subsystem consists of four Harris FV2MF transmitters for video and audio. Cole has indicated that color "enhances detection and recognition in natural terrestrial scenes as well as in other unfamiliar scenes containing color coded information." In a study where target features in the environment were not color coded, no difference was found between color and monochrome conditions. Many studies have been conducted regarding the effects of stereo video on operator performance and have shown that stereo enhances performance for tasks requiring three-dimensional (3-D) perceptual information. However, a study by Kim showed that monoscopic displays can result in equivalent performance when appropriate parameter values are selected and visual enhancement depth cues are presented.Also, a study conducted under Independent Research and Development (IR&D) project D-96D with static images showed no performance advantage for stereo. It is unknown if the performance benefits of stereo video are mitigated as display size is decreased below some minimum size.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Test Summary Report, STV Cable Payout System, April 1991

Author(s): Science Applications International Corporation

OBJECTIVE:

To present a summary of the results of a developmental test for a cable payout system.

APPROACH:

Background information concerning a cable handling system; summary of test results; conclusions; and general discussion.

LESSONS LEARNED:

Cable stiffness and jacket smoothness comparable to the Airlayable cable, tape (equivalent to military duct tape) at the OD essential for maintaining last layer stability, smooth inner tube essential to eliminating tangling due to outer cable loops collapsing, cable pack OD should not exceed 21", and a 0.25" winding pitch should be maintained.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV Cable Payout System, Contract Summary Report, April 1991

Author(s): Science Applications International Corporation

OBJECTIVE:

To present a summary of all work performed in support of the STV Cable Payout System development.

APPROACH:

Discussion of cable payout test plan, cable payout test, cable backup system, and cable level gauge. Copies of the conceptual design of cable backup system and the cable level gauge are included as appendices.

LESSONS LEARNED:

Active payout scheme cnosen for cable backup system. Use of an optical sensor for low cable warning system provides a high level of reliability compared to a system relying on physical contact between the cable and the sensor.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV Cable Payout System, Cable Level Gauge and Cable Backup System, Engineering Sketches, April 1991

Author(s): Science Applications International Corporations

OBJECTIVE:

To provide engineering sketches associated with the conceptual design of the cable level gauge and the cable backup system.

APPROACH:

Two sketches were included for the cable level gauge design entitled Cable Level Gauge Sensor Placement and Modes of Operation, and Cable Level Gauge Hardware Configuration. Three sketches were included for the cable backup system which are entitled Cable Backup System Configuration, Cable Backup System Mock Up Configuration, and Schematic of Cable Backup System Control Electronics.

LESSONS LEARNED:

Reflective tape used with the optical sensor to determine cable level. Estimated dimensions for the cable backup system mock up configuration are 12"x14"x4" deep. Pittman servo motor with 60 in-oz at 2000 RPM was used.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Field Splice for Single Optical Fiber, Kevlar-Strengthened Cable, 16 July 1991

Author(s): Gerardo N Daguio, Dolores M. L. Daguio, and Robert M. Baker

OBJECTIVE:

The purpose of this invention is to provide a means for rapid repair of single optical fiber cables with non-metallic strength members in a tactical environment when spare cables are either unavailable or impractical to deploy. In addition, the splice should meet the following criteria: a) small in size (splice length and diameter) so the repaired cable can be smoothly recovered and/or redeployed using conventional winding or spooling techniques, b) provide low optical splice loss, c) able to be performed within a short period of time, d) retain sufficient break strength of the cable to allow it to be recovered and/or redeployed using conventional winding or spooling techniques, and e) simple enough to require very little training to perform.

APPROACH:

Discussion of background information, description and operation, advantages and new features, and alternatives.

LESSONS LEARNED:

Conventional techniques for repairing optical fiber cables with non-metallic strength members typically utilize fusion splicing or mechanical splices to reconnect the optical fibers and a splice housing to hold and protect the aligned fibers and provide strength for the spliced area. Fusion splicing for repairing optical fibers is unsuitable for use in a tactical environment because 1) it requires the use of electrically powered equipment which could induce explosion hazards and 2) the equipment requires skilled operators. Depending upon the operator's technique used to apply this new non-metallic strength member wrap, the completed splice can be as small as 0.20 inches (5.0 millimeters) in diameter and less than 3.0 inches in length. A splice of this size can be respooled onto a reel if the cable's radius of curvature at the splice is sufficiently large compared to the splice length. The field installation requirement rules out any splicing method requiring adhesives because of the time factor for curing the adhesive and from the standpoint of contaminating the adhesive in the field.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Tech Base Cable Payout Test Results, 10 September 1991

Author(s): A. Koyamatsu

OBJECTIVE:

On 5 September 1991, two UGV Prototype cables were optically monitored during payout, then and rewound during retrieval. STV cable payout and rewind hardware, including the split-tube payout conduit, was used for this test. This memo discusses the test results.

APPROACH:

Discussion of Set-Up, Payout Performance, Optical Performance, and Recommendations.

LESSONS LEARNED:

The payout pack included 5.0 km of 2.0 mm cable on the first spool and 4.8 km of 2.5 mm cable on the second spool. The fiber-optic coupler connecting the two cable lengths had difficulty passing through the funnel, going into the payout conduit. The coupler had to be manually pulled out to avoid damage. During payout of the first 4 km of the 2.0 mm cable, the optical power meter showed -34.97 dB, dropped to -35.5 dB, and rose back to -35. dB. At the start of the last 1 km of payout, there was a break in the optical continuity; however, there were no visible flaws on the cable's out jacket. Further lab analysis concluded that there were at least two breaks in the 2.0 mm cable. Prior to tangling at the last 100 m, the 2.5 mm cable went from -31.34 dB to -31.94 dB. The tangle caused the attenuation to rise ~3 dB. Further lab analysis concluded that the 3 dB attenuation rise came from a factory installed optical splice, which was ~0.5 dB before payout. Limit the amount of 2.5 mm cable to be wound onto the spool to 4.6 - 4.7 km. This will avoid over-packing of the spool. If a decision had to be made at this point as to which cable was superior, I would have to conclude that the 2.0 mm was not acceptable because of the numerous, unexplained breaks in the 5 km length tested. Hence, the 2.5 mm cable proved (for this test) that it is capable of surviving a typical payout/rewind.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle Data Link Analysis, Final Report, 18 February 1992

Author(s): Dr. James Baumann and Keith Thompson

OBJECTIVE:

To perform system and subsystem analysis and research required to support the assessment of the data link, controller and interface between the Operator Control Unit (OCU) and the Surrogate Teleoperated Vehicle (STV); and analysis of the FEedback LImited Control System (FELICS) in order to assess its integration into the STV system.

APPROACH:

Review the Army Operational and Organizational (O&O) Plan, the Marine Initial Statement of Requirements (ISOR) document, the Trade-Off Determination (TOD), and the Trade-Off Analysis to determine the impact of each on the Tactical Unmanned Ground Vehicle (TUGV) system requirements.

LESSONS LEARNED:

Recommended that the primary and the backup communications link between the OCU and the Mobile Base Unit (MBU) be fiber optics and SINCGARS (RF), respectively. Also recommended that SINCGARS be used as the communications link between the OCU and supported elements.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report, DoD Fiber Optic Conference, 28 March 1992

Author(s): Leon Joly

OBJECTIVE:

To attend the 3rd Biennial Department of Defense Fiber Optics Conference.

APPROACH:

Attended various exhibits and the following meetings: Fiber Optic Payout Development, Optical Sensors for Land Applications, Optical Sensors for Environmental Control, Advanced Developments in Fiber Optics, Fiber Optic Payout Systems, Qualification/Implementation Experiences, Secure Communications & Technical Applications, and Industry IR&D.

LESSONS LEARNED:

Characteristics of current single mode fiber are sufficient for handling present and future data rates for tactical UGVs. The fiber supported by transmitters and receivers at both ends should support data rates approaching 200 mbps. With one or more transmitter diodes (or lasers), it is expected that as many as 8 channels of digital color video could be simultaneously down linked which exceeds anticipated requirements for one to three 3.5 mhz color video signals. Cable strength and durability appear to be more than adequate for current needs. Vehicles have repeatedly driven over the fiber and the fiber has been wrapped around the tire of a HMMWV and driven distances resulting in at least 10,000 passages of the tire over the fiber without breaking the fiber. During COEE, the fiber optic cable was inadvertently wrapped around the axle several times before breaking the fiber. Ignoring potential nuclear hardening problems with fiber, the overall risk associated with the production and performance of fiber optic cable is acceptable. Other than the logistics problems associated with retrieving fiber, the main disadvantage of fiber is it's cost ($1.50 per meter) and weight (roughly 15 lbs per kilometer). Cost of fiber is not likely to drop appreciably unless several programs use the same fiber and contract for large production runs. Pigtail should be funded as a means of alleviating the problems associated with the cable getting wrapped around the axle.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: High-Ratio Bandwidth Reduction of Video Imagery for Remote Driving, 20 - 22 April 1992

Author(s): Dale R. Shires, Frank F. Holly, and Phillip G. Harnden

OBJECTIVE:

This paper describes two techniques used to produce low-data-rate transmissions.

APPROACH:

Image compression is performed by an algorithm designed to implement the new Joint Photographic Experts Group (JPEG) compression standard. In the second step, a 90-to-1 bandwidth reduction is achieved by transmitting only one frame every 3 seconds rather than the usual 30 frames per second. By itself, this is unacceptable from a human factors viewpoint because of the large voids in the visual information presented to the remote operator. Therefore, we have developed an image processing algorithm that creates simulated dynamic imagery (synthetic optic flow) during the 3-second intervals. That is, each period consists of one "real" frame and 89 synthetic ones.

LESSONS LEARNED:

The JPEG produces a bandwidth reduction ratio of 25-to-1. By transmitting one frame every 3 seconds, the achieved bandwidth reduction ratio is 90-to-1. Therefore, the overall bandwidth reduction ratio is 25 x 90 = 2250 to 1. The result is smoothly flowing imagery which appears very close to that produced by full bandwidth transmission. It can be seen that, because of the faster movement and expansion in the foreground, there is some resolution loss in the foreground in the later synthetic frames, bu the major features are still clear. Furthermore, the loss of resolution does not appear to be troubling to the operator in viewing the actual dynamic imagery perhaps, in part, because it is immediately followed by a real frame containing full resolution.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	Demonstration of a Unique Method for Remotely Driving a Ground Vehicle Using Only Narrow-Band RF Communications Links, 20 May 1992
Author(s):	Dynamic System Technologies Incorporated

OBJECTIVE:

To present the results of a contract effort to demonstrate the FELICS concept on a test bed.

APPROACH:

Section 1 is an introduction to the report. Section 2 describes the FELICS concept, followed by a specific description of the demonstration system equipment in section 3. Section 4 discusses the functional attributes of the demonstration system. Section 5 discusses the demonstration itself and the results are presented in section 6. A final summary and conclusions drawn are presented in section 7.

LESSONS LEARNED:

Control of the skid-to-steer vehicle using FELICS was demonstrated at a range of frame rates, down to 1 picture every 3.5 seconds (0.3 pictures/sec), at a range of vehicle speeds up to 10 meters/sec (about 22 miles per hour). This control was achieved with sufficiently precise control to go around the test track, and to perform U-turns within the width of the test track. An operator can be trained to use FELICS in ten to twenty minutes. Experience in driving the vehicle being controlled is completely unnecessary. The principal operator of the OCU demonstration has never driven a skid-to-steer vehicle other than through FELICS. From a control-system standpoint, control of a skid-to-steer vehicle is a more difficult task than control of a steered-wheel vehicle, because of the non-linear steering characteristics and their wide variation on different types of surface. At Demo I, DSTI demonstrated control of the test vehicle on the only two types of surface available at the test site: a prepared track covered with loose dirt, and a much firmer grassy surface. Other DSTI testing, however, has shown excellent controllability on a much wider range of surfaces, from dry asphalt to slippery mud. a significant advantage to the combination of FELICS and skid-to-steer, is that the operator is afforded unlimited freedom in maneuverability. The operator is not constrained to any turn radius and therefore does not need to be concerned about that aspect of the vehicle.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: An Assessment of the Survivability of Fiber Optic Cable for the Tactical Unmanned Ground Vehicle, 29 July 1992

Author(s): Erika M. Swinson and Virginia Young

OBJECTIVE:

The main objective of this test was to evaluate several mechanical aspects of fiber cable and to assess its feasibility for application to the TUGV.

APPROACH:

Tests were performed to evaluate the lightest weight, fiber optic cable that could withstand rugged, battlefield environments. The three mechanical tests performed were: 1) Tensi Strength (measures a cable's ability to resist being pulled apart); 2) Compression (measures a cable's ability to resist signal loss as a result of being driven over by a vehicle); and 3) Bending Test (measures a cable's ability to resist signal loss as a result of being driven over by a vehicle).

LESSONS LEARNED:

Conclusions indicate that fiber optic cable is survivable for the TUGV application. Field tests at Fort Hunter Liggett have shown that for payout 100 lbs tensile strength is recommended. This means only Brand Rex failed to meet the requirement. OCC #1, OCC #2, AT&T, and Belden will exceed the requirements for payout. The bending and compression test gave good indications as to which cables could handle "drive over." OCC #1, OCC #2, and AT&T performed best in micro-bending. For compression AT&T and OCC #2 were well suited. Belden and Brand Rex do not appear to have adequate survivability for the TUGV application. For tensile strength Belden out performed the other cables. This can be attributed to the fact that it had a larger diameter and two jackets. OCC #1 performed better than Belden and Brand Rex overall. However, it did not do as well as OCC #2 and AT&T. For use with the TUGV project I recommend AT&T and OCC #2. Since tests came out close on both brands it was decided to recommend both.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A Low-Cost Multichannel Digital Fiberoptic Link

Author(s): Donald G. Krantz and Roger D. Steen

OBJECTIVE:

This paper describes the low-cost digital fiberoptic transmitter/receiver circuit card set developed by Alliant Techsystems during the TeleScout program. The paper describes the overall concept and the detailed design of the board set, including block diagrams.

APPROACH:

Discussion of the original purpose of the link, other possible applications, projected uses, major design constraints, video subsystem, audio subsystem, and data channels.

LESSONS LEARNED:

Communication requirements between the TeleScout and the Operator Control Station (OCS) include: 1) stereo driving video (two channels, RS-170A), vehicle to OCS, 2) digital status (about 100 bits/second), vehicle to OCS, 3) three audio channels (20 kHz minimum bandwidth, 40 kHz preferred), vehicle to OCS, 4) digital control (about 500 bits/sec), OCS vehicle, 5) audio channel (3 kHz minimum), OCS to vehicle, 6) minimum communication distance of 10 km, 7) additional video channels to allow operating reconnaissance and surveillance cameras simultaneously with the driving cameras (vehicle to OCS), 8) audio talk-back between the safety rider and the teleoperator, 9) video sync channel, OCS to vehicle, to allow syncing with test recording equipment and genlock of the onboard cameras, 10) spare digital control channels to allow expanding the vehicle payload systems, 11) increased fiberoptic drive capability (design margin, noise immunity, compensation for variations in light levels due to cable flexing motion), and 12) ability to use a single fiber. The set as configured is capable of transmitting four channels of NTSC (RS-170A) video, four 40 kHz audio channels, and three 2.5 MBaud serial digital instrumentation channels, each direction, on one single-mode fiberoptic cable. The mixture of video/audio and digital instrumentation channels can be easily modified. The cost of a production bi-directional system, including laser drivers with a 30 km range, could be as low as $8,000 (ruggedized but not MIL-STD).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Fiber Optic Link Concept for Caleb (Tactical Unmanned Ground Vehicle)

Author(s): Steve Koutsoutis

OBJECTIVE:

To describe the fiber optic link concept to be used for the Caleb.

APPROACH:

Discussion of the proposed single mode single fiber cable to be used in Caleb, fiber optic link budget, previous CECOM experience with fiber optics, light source trade-off, detector trade-off, component selection, and advantages of using fiber. Also included was a table comparing several navigation units.

LESSONS LEARNED:

Characteristics of proposed single mode single fiber cable: outer diameter - 2.5 mm (max); attenuation - 0.5 dB/km at 1310 nm/0.3 dB/km at 1550 nm; bandwidth - > 50 GHz-km; radiation hard; stable performance versus temperature; immune to EMI; and weight - 6 kg/km. The fiber optic cable assembly (SFOCA-3) was chosen because of its low loss characteristics, small diameter, low weight, ease in payout (soft structure), and overall ruggedness for use in tactical environments. The light source (laser diode) was chosen because of its high bandwidth, small spectral width, and higher power coupling efficiency. These characteristics are necessary for low dispersion and crosstalk for the proposed full-duplex wavelength division multiplexed system over a single fiber. The detector chosen was a pin photodiode. Wavelength division couplers are necessary for full-duplex communication over a single fiber. Advantages of using fiber include: 1) can support multiple video signals because of its inherently large bandwidth, 2) conforms to Caleb stealth requirement (no RF signature), 3) using optical switches and couplers, a single control station can be configured to control several Calebs, and 4) field proven technology. Projected fiber optic link cost (including cables, O/E and E/O interfaces, and packaged 30 km continuous length cable for deployment) will be on the order of $40K for quantities greater than 500. Advantages of using RF are: non tethered vehicle allocation considerations. Disadvantages of using RF include: 1) frequency bandwidth allocation considerations, 2) 2-4 radios required, 3) excessive system weight, 4) potential voice override if in net, 5) power consumption, 6) intensive voice compression requirements for NLOS, 7) potential cosite interference of multiple antennas, 8) antennas required, 9) security issues of RF link depending on radio type, and 10) wideband requires line of sight consideration/relay may be required for system support.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Human Factor Issues Associated with Image-Compression for Low Data Rate Remote Driving

Author(s): Tamara Adlin

OBJECTIVE:

To outline the human factors issues inherent in the transmission of video data over a low bandwidth secure radio channel, necessary for battlefield teleoperation of remote platforms.

APPROACH:

Discussion of the low data rate remote driving project, the problem of human factors for image-compression, the remote driving task, the Oak Ridge National Laboratory's compression system, contrast and resolution, field of view (FOV), foveal windows, frame rate, color, depth perception, stereoscopic video, depth cue augmentation, orientational awareness, motion sickness and fatigue, and training.

LESSONS LEARNED:

FOV afforded to the operator is critical to his or her confidence and ability in remote driving. The camera currently specified for remote driving imagery at HEL has a horizontal FOV of 55 degrees. The human binocular FOV is almost elliptical, covering approximately 190 degrees horizontally and 100 degrees vertically. The covered area includes peripheral vision, of increasingly lower resolution with distance from the foveal region. A narrow FOV is fine for driving on paved roads with well-defined edges, and some aspects of the off road driving task can be well served by narrow FOV, high resolution cameras. The foveal window is one of the most effective means of reducing transmission rates. It is necessary, however, to re-examine the design of the foveal window. Remote driving experiences at HEL have led to human factors researchers to believe that high frame rates are extremely important to the operator. Smooth motion is familiar from on-board driving experience. Jumpy, low frame rate video is difficult to trust. It is difficult to believe that the video is "keeping up" with the vehicle and to trust that nothing will suddenly pop up into view to late to perform avoidance maneuvers. Color video requires three times more image transmission than black and white video; however, color video provides contextual information over the whole image, improves depth perception, and defines obstacles where they might otherwise blend into the background.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Lightweight Tactical Single-Mode Fiber Optic Cable

Author(s): A. Nobunaga

OBJECTIVE:

This paper will review the development of the present cable design including the selection of the optical fiber, strength member jacket material, and manufacturing methods. Included is a summary of all the cable designs tested, the test methods used, and those test results which led to specification of the present design.

APPROACH:

Discussion of cable requirements, preliminary cable designs, cable testing, present cable design, manufacturing problems, and conclusions.

LESSONS LEARNED:

A compressive load test was performed on the seven remaining cable designs. All the cables were subjected to 4,450 N load with no visible deformation of the cable jackets. The goal of this cable development program was to develop a tactical, single-mode fiber optic cable meeting the following requirements: protection for a single optical fiber, high quality optical transmission, and minimum cable diameter (< 2.0 mm) and weight (< 6.8 kg/km). Cable ranging from 1.0 mm to 2.5 mm were tested to arrive at the present cable design. Test results were used to evaluate cable design approaches and aided in material selection. Trial run lengths of present cable were received in July 1987. This cable had a 2.1 mm overall diameter cable with a polyurethane jacket and KEVLAR strength members and weighed 5 kg/km. It had a n average attenuation of 0.45 dB/km and 0.3 dB/km at 1310 and 1550 nm, respectively. During temperature cycling the cable exhibited an attenuation increase of 0.29 dB/km at 1550 nm. Recent improvements on optical fiber design indicate that cables with better optical qualities can be produced. Dispersion shifted optical fibers could improve the temperature cycling performance of the cables. With the addition of this new fiber, then a truly tactical single-mode fiber optic cable can be produced.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: PRECOM (PREdictive coding using the COsine transform and Motion compensation); A TV Compression System for Moving Vehicles

Author(s): Delta Information Systems, Inc.

OBJECTIVE:

To provide a description of the PRECOM compression system for moving vehicles.

APPROACH:

Discussion of system considerations, image format, and the PRECOM algorithm.

LESSONS LEARNED:

The function of the PRECOM system is to digitize video signals produced by cameras in a moving vehicle, and to reconstitute the original video signals at a remote location after transmission over a radio link. The data rates produced by the Encoder in the vehicle must be very low, in order that the digital signal can be transmitted over low bit rate radios. The Encoder shall accept RS-170 monochrome video. The Decoder shall produce RS-170 monochrome video. Forward Error Correction (FEC) will be used to reduce the bit errors caused by the radio link. The goal is to provide useful images at a random bit error rate of one error in 2,000 bits (5 x 10 -4). The system shall provide three operator-selectable horizontal resolutions: 128, 256, and 512 pixels per line. The vertical resolution shall be 240 lines per frame. The system shall provide five operator-selectable field rates: 15, 10, 7.5, 6, and 5 fields per second. In addition, a freeze frame mode shall be provided that will encode a selected field with the best possible resolution. In order to increase compression even further, foveal vision is employed, whereby the clarity and accuracy of the image varies over the field. The highest resolution is used near the center of the field, with the resolution gradually decreasing towards the edges and corners of the image. This is achieved by varying the coarseness of quantization or the highest frequency coefficient used, or both, over the field. Thus, the bits that are saved in coding the corners can be used to make the center of the image as clear as possible.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Preliminary Procedures for , and Preliminary Results of, UGV Cable Survival Tests

Author(s): Jack E. Holzschuh

OBJECTIVE:

To present procedures for testing UGV cable survivability and preliminary test results for several candidate UGV cables.

APPROACH:

This memo discusses the cables that were tested, the test procedures used, and the results of the tests, in that order.

LESSONS LEARNED:

In this particular test series, the air layable cable demonstrated a capability to survive far more abuse than either of the AT&T cables. Of the two AT&T cables, the one with the tougher buffer material survived longer. The failure mode for the AT&T cables seemed to be abrasion of the outer jacket, resulting in exposure of the buffered fiber, with subsequent breaking of this fiber. The failure mode for the air layable cable seemed to be a "cut through" type. This is believed to be caused by running over a sharp rock which actually cuts the jacket and breaks the fiber simultaneously. Laying the fiber at an angle to the tread seems to subject it to more abuse than laying it perpendicular to the tread. This was readily apparent in test #5. All three cables survived longer on a MacAdam road than on the gravel covered pavement. On the pavement/gravel, eight 180 degree turns per mile were required to stay on the course. On the road (test #5), only about two 90 degree turns per mile were required.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

OPERATOR CONTROL UNIT (OCU)

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Helmet-Mounted Visual Display Systems for Teleoperated Vehicles, July 1986

Author(s): John O. Merritt and Stephen P. Hines

OBJECTIVE:

To develop and evaluate a variety of helmet-mounted display concepts in order to determine specifications for a ruggedized fieldable prototype, to be used in operational testing of TOV and AROD. Evaluate various ways of allocating the pixels available (in 60 525-line video frames each second) to either forward stereo vision or non-stereo peripheral vision. Determine the optimal trade-offs in field of view (FOV) versus resolution (along with other factors such as color, motion/time resolution, shape of FOV, etc.). Determine what regions of peripheral vision are most useful in driving teleoperated vehicles. Determine the minimum needs for central high-resolution vision and stereo overlap.

APPROACH:

Display concepts were innovated by alternating group sessions with individual efforts. The concepts thus developed were evaluated through group discussion followed by quick prototyping of the more promising concepts. The remainder of this report describes the helmet-mounted visual display concepts thus produced, as of June 1986, and preliminary evaluations of each concept.

LESSONS LEARNED:

Operators driving the TODD tested David Smith's idea that peripheral vision was useful for keeping an eye on the road when looking 45 degrees to the side with the central stereo display. This function of stereo vision was also tested by driving a NOSC off-road vehicle with a face-shield that restricted peripheral vision. These test confirmed the importance of this function of peripheral vision. Another important function of peripheral vision seen in these informal test was knowing when to turn around the corner of a building or an obstacle, such as a rock or tree. The value of even poor-resolution peripheral "windows" was seen at several instances where vehicles approaching from the side, and other such targets, were seen easily, but would have been missed with only a central field of view.It was observed that image scale was critical between the central view and the flanking views. Objects seen in the central view would appear in the side window before leaving the central window. The lack of this match between central and side proved to be disturbing to the operator's sense of where things were in space around the vehicle. Gaps between the forward view and the side views are not the problem; it was just the unnatural way objects transited from front to side that caused problems.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trade-Off Determination for the Operator Control Unit of the Caleb Unmanned Ground Vehicle, February 1990

Author(s): Combat Service Support Division, US Army Labcom, Human Engineering Laboratory

OBJECTIVE:

To present five concepts which are potential candidates for the OCU of a Caleb/TUG-V.

APPROACH:

Each concept is discussed in some detail, with design decisions explained in context. Major advantages and disadvantages are discussed, and a recommendation made. Four of the concepts are feasible with today's technologies, and the fifth is not far off. None of the concepts meets all the desired characteristics of the Caleb draft O&O, nor those of the Marine Corps draft ROC, but one or more likely provide an acceptable solution.

LESSONS LEARNED:

The display technology needed to build a good fieldable stereo display appears temptingly close, but is not quite here. The required combination of size, chromacity, and ruggedness is not known to be available. Remote driving has been demonstrated using displays as large as 40" and as small as 5". Operators complain about displays much smaller than 7", however. Color has been demonstrated to aid in object recognition in Sandia tests of remote driving, and it is overwhelmingly favored by operators. Test data shows it is not significantly better in operator performance, however. Object recognition would seem an important aspect of driving, so color is highly desirable. Operators dislike the joystick control approach, and prefer even a small steering wheel or yoke. They also prefer a large screen (19" or greater). TMAP experience indicates that the communication hardware drives the power and cost of the OCU. Field testing of TMAP engineering prototypes emphasized two things. First, it was very difficult for the soldier to find his way to a designated destination using only the driving camera display. Landmarks such as pathway intersections were difficult to see in the two-dimensional video image, especially given the complete lack of peripheral vision. Second, given a navigation display in grid coordinates only (e.g. vehicle represented graphically on grid coordinates with no map detail), the designated soldiers performed poorly. Experience with teleoperated vehicles has invariably emphasized that engine noise is vital information for the operator concerning the status of his remote vehicle.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Battery Requirements for the "Caleb" Operator Control Unit, February 1990

Author(s): Carl Berger

OBJECTIVE:

To present information concerning battery requirements for the "Caleb" Operator Control Unit.

APPROACH:

Discussion of power requirements for both configurations and available battery technology.

LESSONS LEARNED:

Upon review of the referenced documents, the "Caleb" OCU is composed of three basic components - the display, the computer, and the transmitter and receiver for the fiber optic signals. The power estimates for the three components are as follows for each OCU configuration. Manportable OCU: Display - 25 watts; Computer (laptop) - 6 watts; Receiver/Transmitter (RT) - 3 watts; Total - 34 watts. Suitcase OCU: Display - 40 watts; Computer (laptop) - 6 watts; Receiver/Transmitter (RT) - 3 watts; Total - 49 watts. To obtain the lightest and most compact configuration for the OCU, lithium throwaway batteries should be used. The power projections of paragraph 3 assume that the computer is a laptop system. More sophisticated displays that utilize a digital map that will allow the operator to track the "Caleb" vehicle will require a computer equivalent to a desk top system. The power projections for the Suitcase OCU will become the following. Suitcase OCU: Display - 40 watts; Computer (laptop) - 200 watts; Receiver/Transmitter (RT) - 3 watts; Total - 243 watts. There is no battery system except sealed nickel cadmium batteries or lead acid that can meet the 243 watts requirement. The driving factor for the OCU is power and availability of a practical portable power source. Based on this office's power surveys of facsimile components, this office recommends that HEL build their OCU requirements around a laptop computer with 1 display unit.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV Driving Controls Comparison Test Results, 22 October 1990

Author(s): A. Koyamatsu

OBJECTIVE:

To describe comparison test results used to identify a controller for the STV program.

APPROACH:

The comparison criteria used to evaluate the four controllers was based on which control option best satisfied control sensitivity, ease of learning, natural to operate, driving efficiencies, minimal operator fatigue, and driver confidence.

LESSONS LEARNED:

The TOV type controller provided the best performance, however for portability, the motorcycle steering handle or the integrated steering wheel was recommended.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV Graphics Overlay System Overview, 7 February 1991

Author(s): Lloyd Yano

OBJECTIVE:

To present a description of the STV graphics overlay system.

APPROACH:

Discussion on the four different display screens available from the STV graphics overlay system. In addition, a listing of the STV graphics system hardware is included along with the modifications needed for the US Video VGA overlay board; configuration drawings for the 6C22 microprocessor; and configuration drawings for VGA overlay board.

LESSONS LEARNED:

The first display is the drive data screen and provides vehicle attitude information such as pitch, roll, and vehicle heading. A bearing to waypoint cursor and distance to waypoint readout is included in this display. Camera heading, and speed is also provided as well as annunciators for safety and mission critical conditions. The second display is the surveillance screen and provides surveillance sensor bearing, vehicle heading and various annunciators. A target bearing cursor, distance to target readout and target coordinates is also provided. Cross hairs can also be provided is not included in sensor video. The third display is the map screen and provides a grid of the operational area and plots the vehicle position and track, the relative positions of the base and current target are also plotted. Also provided is annunciators, vehicle heading, sensor bearing and various system readouts. This display can be accessed while in either the drive or surveillance modes. The fourth display is the status display which provides a text listing of all of the STV system's parameters. This display is used mainly as a diagnostic tool but can be easily accessed from any mode by the operator if more detailed information than provided by the other displays is required.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV HMD September - FY91 Year End - Status Report, 2 October 1991

Author(s): S. W. Martin

OBJECTIVE:

To present the status of the STV HMDs.

APPROACH:

Discussion of two STV HMD subsystems, SAIC delivery order for prototype monitors status, parts status, issues, plans, and the budget.

LESSONS LEARNED:

Two STV HMD subsystems have been completed and are ready for delivery. These units utilize the ISTC monitors as the SAIC new design monitors have still not been delivered. Power consumption is under 50 watts from 20-28 vdc, the units are painted a shade of desert tan, are packaged totally in portable cases, include the required I/O cable to hook up to an STV OCU, and have technical manuals(NOSC TM-647 Draft) to go along with them. Cost of the HMDs is currently $64,829.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: A Helmet Mounted Display System for Control of an Unmanned Aerial Vehicle

Author(s): B. Welch, R. Kruk, and M. Shenker

OBJECTIVE:

To present a discussion of a helmet mounted display system for use with a UAV.

APPROACH:

Discussion of Autonomous or Teleoperator Control, Helmet Display Approach for Teleoperator Control, Critical Display Parameters, Area of Interest Concept, Psychophysical Aspects, Resolution, Field of View, Stereo Versus Non-stereo, Design Considerations, DataLink, and Resolving Research Issues by Simulation.

LESSONS LEARNED:

The normal field of view of a person is about 190 degrees horizontal x 110 degrees vertical and a person with normal acuity of 20/20 can distinguish spatial frequencies of about 0.6 line pairs per arc minute. Duplicating this resolution over such a field of view using sensor system operating at normal field rates would require a bandwidth of about 1000 MHz. The full field of view of the FOHMD is 127 degree horizontal by 66 vertical. The results indicate that stereo imagery provides a significan' performance advantage. This is despite the fact that: a) the image generator has a stereo acuity considerably inferior to that of a normal person, b) the imagery is collimated, c) convergence is fixed at 30 feet. Accommodation and convergence cue then, tended to conflict with disparity information, although the latter was somewhat accentuated by a 75 mm. interpupillary distance setting. On the positive side, monocular depth information such as perspective and interposition were correct. The prominence of stereo upon performance, given the list of characteristics which would tend to reduce the effect, was somewhat surprising. In tasks involving close approach to other objects, it may be of considerable value. The real time video link between the UAV and operator is likely to be the limiting factor in the overall performance of the system even in those applications where electronic emissions are not important from the standpoint of maintaining secrecy. A direct fibre optic link would provide an adequate bandwidth and maintain secrecy but would certainly limit mobility. As bandwidth will be a major issue, factors such as reducing resolution in the peripheral areas of the field of view, optimizing the inset size, using colour only in the inset need to be investigated.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Comments on Prototype AOI HMD

Author(s): H. Spain

OBJECTIVE:

To present a general summary of comments and experiences concerning this system.

APPROACH:

Discussion was broken down into positive comments and negative comments.

LESSONS LEARNED:

Moderately prolonged use of this HMD (i.e. 30 minutes +) might possibly induce significant fatigue in some users. Though binocular rivalry was not noticeable in the insert area or the wider peripheral areas, it did occur in the immediate vicinity (i.e. 2 to 3 degrees) of the sharp luminance step between the insert and the surround. For most observers, flickering of the wide-field channel was very apparent, especially if they concentrated their attention on the flicker. the flickering sensation was most pronounced for brighter areas of the display (which accords with the psychophysical function relating flicker to overall intensity). Flicker was also more apparent in the extreme peripheral areas of the display (also in accord with the psychophysical literature). For some observers, the flicker produced sensations of "phantom" shapes, false color, and movement - all of which are frequently reported sequelae to flickering light stimulation. One final aspect of the display which concerns me is the possibility of exposing users to ionizing radiation (especially "soft" x-rays) due to the closeness of the eye to the CRT surface. This is not a problem with the current viewfinder CRT which is in the hi-res insert channel, but it may be a problem with the 3" CRT. Apparently, from some discussions I had several years back with video engineers at RCA, the voltage applied at the CRT's anode is the primary determinant of radiative emissions.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Flat Panel, Color Video Displays, Model 900 Series, Preliminary Specifications

Author(s): Videospection

OBJECTIVE:

To provide a description of flat panel, color video displays.

APPROACH:

Discussion of features, specifications, and operating environment.

LESSONS LEARNED:

The 900 series LCD display monitors utilize a solid state, high density, thin film transistor panel, liquid crystal display for the display of color or monochrome composite video signals. The nature of the liquid crystal display panel permits its use in applications where conventional CRT displays are unacceptable due to weight, power consumption, heat dissipation, and size. No x-ray emissions or implosion hazards exist since the display does not use a cathode ray tube. The small, light weight display units have low power consumption and are immune to RFI and EMI emissions. They are ideally suited for use on military vehicles, aircraft, and portable field operations. The size of the 900 series ranges from 3.3 inches to 10.4 inches. The pixel count for the 900 series is as follows: 442 x 238, 480 x 239, 480 x (300x3), and 480 x (640x3). Viewing angles are +/- 30 degrees and +/- 45 degrees. Power consumption for the 900 series ranges from 7 - 10 watts. Weight for the 900 series ranges from 0.5 lbs to 4.5 lbs. The 900 series can be operated in temperature ranges from 0 degree C to +65 degree C, be stored in temperature ranges from -20 degree C to +65 degree C, withstand vibrations from 5-500 Hz (5 g) and 3 axis, 11 ms, 15 g shocks.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

OVERALL UGV SYSTEM

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Test and Evaluation of the PROWLER, 26 August 1985

Author(s): Virginia Young

OBJECTIVE:

Evaluate the ability of the PROWLER to employ the dual threat of the SPIKE hypervelocity kinetic energy penetrating rocket and the Rifleman's Assault Weapon(RAW).

APPROACH:

A weapons package was designed so the SPIKE rocket system and a RAW(in this case the VIPER) could be mounted on the PROWLER. Preliminary test firings were conducted at Redstone Arsenal to establish correct firing procedures for each weapon. A target(M113) was positioned approximately 300 meters from the PROWLER control van. The PROWLER was then moved remotely into position and stationed itself approximately 150 meters from the target. Each weapon was then remotely fired at the target.

LESSONS LEARNED:

A teleoperated unmanned vehicle should have light weight for maneuverability(PROWLER - 3700 lbs), walk-the-dog capabilities, color/stereo vision (recommended), a low center of gravity, a moveable(and lockable) turret, automatic iris on driving camera for varying light conditions, a wider field of view (FOV), tires invulnerable to small arms fire (Run-flat tires), and a night sight or image intensifier for night operations and improved driving capabilities. Current camera being used had drift which made sighting and targeting difficult. Backblast from weapons system damaged mast wire attached to mast camera and radio antenna.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: The PROWLER, 1985
Author(s): Robot Defense Systems, Inc.

OBJECTIVE:

To present a description of the PROWLER system.

APPROACH:

Discussion of the PROWLER vehicle, sensors, and weapons.

LESSONS LEARNED:

The PROWLER has the following specifications: Undercarriage weight - 3,700 lbs; Payload weight - 2,000 to 4,000 lbs; Maximum speed with 2,000 lb payload - 27 kph; Number of wheels - 6; Total draw bar pull - 4,297 lbs; Engine - 65 hp air cooled diesel engine; dual electrical motors, hydrostatic drive; Observation - three closed-circuit television cameras on-board, with one affixed atop a mast that can be raised seven meters above the robot platform, CRT for video monitoring at operator's console; Guidance - CRT at operator's console with map graphics, vehicle location and directional orientation; Diagnostics - CRT at operator's console displays status of all on-board systems; Computer - 32 bit microprocessor, Motorola 68000; Basic platform - 10' long, 7' wide and 7' high; Mobility - turning radius of 5', 250 kilometer range, 2 kilometer average distance for control from console to vehicle, skid-steering, and 60% slope negotiation; Sensors - triple camera video system with various night vision options and split screen capability, audio feedback to operator with directional and/or non-directional pickups, laser rangefinders for navigation, fluxgate with optional directional gyro, multi-axis vehicle attitude sensors, distance measuring equipment for vehicle motion, armor impact sensors detect projectile impingement on vehicle, battlefield surveillance doppler radar, electromagnetic motion detector (stationary vehicle could detect moving targets in foliage and can operate either independently or in conjunction with the seismic system), seismic monitor for detecting sub-audible ground vibrations made by men or vehicles, infrared scanners (FLIR), bistatic illuminator radar; Weapons - M 60 Machine Gun, TOW1 and TOW2 Anti-Tank Missiles, HELLFIRE Tactical Missile, VIPER Light Anti-Tank Missile, Stinger Guided Missile, M9E 1-7 Portable Flamethrower, and M202A2 60 mm Multi-shot Flame Weapon; Chemical detection - GFE M8A1. Radio communications via an error detecting packet switching network. All software written in Motorola 68000 Assembly and Pascal Languages for real time speed and efficiency.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	Draft Required Operational Capability (ROC) for a Teleoperated Vehicle (TOV) System, 7 May 1986
Author(s):	U. S. Marine Corps

OBJECTIVE:

To provide a description of the required operational capabilities for the TOV.

APPROACH:

Presented a discussion on the need, threat and operational deficiency, operational and organizational concepts, essential characteristics, inter/intraoperability and standardization requirements, related efforts, technical feasibility and energy/environmental impacts, life cycle cost forecast/estimate, manpower requirements, training requirements, and amphibious/strategic lift impact.

LESSONS LEARNED:

Essential characteristics: 1) Vehicle speed equal to or better than the speed of a HMMWV under similar on and off road conditions; 2) Move cross-country for 1 hour, or, out to a fiber optic cable payout distance of 25 kilometers. 22-hours stationary operation at a remote site with alternating 4-hour silent mode and one-half hour recharge periods with the TOV engine running. The TOV shall be capable of performing all mission functions during silent mode and recharge period. Cross-country movement back to mission start point. If the TOV is not required to return to its start-point, e.g., if it will be picked up by an advancing unit, then it could operate out to 50 kilometers from its control station; 3) The onboard TOV system will consist of a pair of cameras which provide a stereoscopic visual image to the operator at the control station. The cameras will be mounted on a pan and tilt assembly and their movement will be remotely controlled by the operator's head movements. Horizontal scan - +/- 170 degrees relative to vehicle longitudinal centerline. Vertical scan +80 degrees to -30 degrees relative to vehicle horizontal datum.; 4) Binaural microphones will be mounted on the same pan and tilt assembly as the camera system. The acoustical sensor system will allow normal human sound localization capabilities at the remote site; 5) During daylight, detect and acquire a moving tank-size target at 4000 meters, identify at 2000 meters. At night (1/4 moon), detect and acquire a moving tank-size target at 2000 meters, identify at 1000 meters; and 6) safely arm/fire the TOW missile, M2 machine gun, or the MK19 grenade launcher.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Draft/Strawman Teleoperated Mobile Anti-Armor Platform (TMAP) Required Operational Capability (ROC), June 1986.

Author(s): U.S. Army Infantry School

OBJECTIVE:

To provide a description of the required operational capabilities for the TMAP.

APPROACH:

Discussion of the need/threat, timeframe and IOC, operational and organizational plan (O&O Plan), essential characteristics, technical assessment, logistics support plan, training assessment, manpower/force structure assessment, standardization/interoperability, life cycle cost assessment, and milestone schedule.

LESSONS LEARNED:

Essential characteristics and requirements of the TMAP are as follows: 1) the system will include as many as four (4) mobile platforms (MP) which can be controlled by onboard software (artificial intelligence) or from a single control station, 2) the acquisition of the TMAP system capabilities will be achieved through a phased approach. The first, or interim system will possess capabilities obtainable with current technology. The objective system will be achieved through enhancements achievable through technology growth, 3) weapons and weapon components which may be carried by the MP and operated by the system include - TOW, Dragon, Machine-gun (specific type/model TBD), Mortar (81mm), Target Designator (specific type/model TBD), and Mines, 4) sensors which may be carried by the MP and operated by the system include - TV, Acoustic, IR, RF (active or passive), and NBC, 5) the MPs may be up to 4 km from the control station, 6) data/information communicated between the MP and the control station will be accomplished by means of a secure, ECM resistant data link, 7) the MPs will be capable of speeds up to 20 kph on smooth terrain and will be capable of traversing and operating over rugged terrain. The MPs will be capable of negotiating obstacles (e.g. logs, rocks, trenches, curbs, etc.) up to 0.3 meters in height or depth, and capable of negotiating forward slopes up to 40% and side slopes up to 20%, and 8) excluding the sounds produced by weapons firings, the MP will exhibit a noise level of less than 40 db during combat operations.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Concept Formulation Package (CFP) for Teleoperated Mobile Anti-Armor Platform (TMAP), July 1986

Author(s): Triad Microsystems, Incorporated

OBJECTIVE:

This document provides information necessary to support a decision to proceed with the acquisition of the TMAP through an NDI, Category C2 procurement.

APPROACH:

This Concept Formulation Package (CFP) contains the results of analyses and system engineering performed in the concept exploration/Proof-of Principal phase of the acquisition process. Paragraph 2.0 provides a general description of the proposed TMAP system. Attached appendices provide the following: 1) Trade-Off Determination (TOD - partially completed), 2) Trade-Off Analysis (TOA - TBD), 3) Best Technical Approach (BTA - TBD), 4) Cost and Operational Effectiveness Analysis (COEA - TBD).

LESSONS LEARNED:

The primary use of the interim TMAP system will be as a company level weapon system which will provide the commander with the capability to semi-automatically perform infantry tasks which when performed by infantrymen might produce high casualties. The system concept involves utilization of a control station (CS) subsystem for remote control of mobile platform (MP) subsystems and their constituent sensor and/or weapon suite. Remote control is accomplished by means of a data link between the two subsystems. The control station subsystem includes the operator and the control/monitoring equipment (processor, display, communications, etc.), while the mobile platform subsystems will include vehicle, communications, control, weapon, and sensor equipment. The system concept also includes a transport subsystem (TS) for movement of the MPs about the combat area. Upon receipt of mission alert, the TMAP is configured and initialized to perform the assigned mission. The system is then placed in standby pending receipt of mission execution orders. When execution orders are received, the operator will begin deployment of the system. Following occupation of deployment sites by the MPs, surveillance is begun using onboard sensors. Data is collected, evaluated, disseminated, and displayed using the onboard sensors, onboard processing at the MP and CS, and the TMAP data link. When targets are detected/acquired, the TMAP operator assigns an appropriate weapon system and attacks the target in accordance with predetermined rules of engagement.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Robot Sentry, 17 July 1986

Author(s): Sandia National Laboratory

OBJECTIVE:

To discuss the Marine Corps' robotics program.

APPROACH:

Discussion of the Robot Sentry.

LESSONS LEARNED:

The Robot Sentry consists of a Transportable Sensor Pod (TSP) and a Monitor and Control Station (MCS). Communications between the TSP and the MCS is through a fiber optic link. The TSP is positioned in the field using a Brunton M2 pocket transit. The transit provides reference points to enable the MCS to calculate x, y, z co-ordinates to guide artillery. Range information, up to 10 KM, is provided by a GVS-5 laser range finder. All sensing by the TSP is passive except for momentary laser ranging when actuated by the operator. Once deployed, a TSP can remain as a covert observer for an extended period. The TSP consists of a day/might imager, CCD TV camera, laser rangefinder, and microphones. The day/night imager is a Pulnix model DN-500 image intensifier system. The TV camera is a CCD type with 280 horizontal x 350 vertical lines resolution. The imager is a second generation microchannel plat intensifier. The intensifier allows the camera to operate over a wide range of light conditions, from 10^5 lux (bright sunlight) down to 10^{-3} lux (starlight). The imager is also equipped with a 10:1 zoom lens (16mm - 160mm). The wide angle field of view is 43.36 degrees, 400m @500m. The field of view at max zoo: is 4.35 degrees, 40m @500m. The pan and tilt unit is microprocessor controlled and has two modes of operation. In the manual mode the pan and tilt is controlled directly by the operator at the MCS using joysticks. In the automatic mode the microprocessor will control the pan and tilt tc repeat a pattern of movements previously entered by the operator. The three microphones installed on the TSP provide sound magnitude and direction by computing a time-of-arrival correlation. An additional audio output is provided to the operator at the MCS. The TSP also provides optional interfaces for up to five Tactical Remote Sensors.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Concept Evaluation Program Test of Robotic Ranger, Final Report, August 1986

Author(s): U.S. Army Infantry Board

OBJECTIVE:

To assess the capability of the Robotic Ranger to employ Infantry weapon and reconnaissance systems. Test results will be used by the U.S. Army Infantry School (USAIS) in making decisions concerning further development of such devices.

APPROACH:

The test was conducted at Fort Benning, Georgia, from 19 May through 17 June 1986 under both day and night conditions. All events were performed during daylight. Night missions were attempted but were unsuccessful due to the limitations of the low light level camera. No missions were conducted when it rained. Four infantry soldiers (11B, E3) were trained to operate the RANGER using the remote control console. Because of the experimental nature of the RANGER, no operator maintenance was performed. All maintenance was completed by the contractor.

LESSONS LEARNED:

Skill level 1 map reading proficiency alone does not qualify the test soldier for navigation of the RANGER. Test soldiers were unable to accurately relate the video display of the terrain to their maps. Each soldier required assistance to navigate the RANGER from one point to the next. The test soldiers very quickly mastered the mechanical control of the RANGER from the control console. The steering and motion control "joy stick" was very easy to use. Training is required in associating map data to the actual terrain features when using the control console displays (camera, CRT, grid display). During the machine gun live fire, the camera vibrated so much that the soldiers could not observe the impact of the bullets and could not make burst-on-target (BOT) corrections; however, they were able to hit some targets. During day firing 43.3 percent of the targets were hit. During night firing 30 percent of targets were hit. The stability of the RANGER as an AT-4 firing platform allowed the test soldiers to successfully engage targets at 270 meters and 420 meters with both the 9-mm subcaliber device and the AT-4 TP-T missile. During the live firing AT-4 event, a 9-mm subcaliber round was inadvertently fired. Investigation revealed that the failure of a transistor switch in the firing circuit permitted a bypass of the normal firing command sequence. This design inadequacy, which could result in the inadvertent launch of an AT-4 HE round, is a safety hazard.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TMAP - General Dynamics, 1986

Author(s): General Dynamics Land Systems Division and Unique Mobility, Inc.

OBJECTIVE:

To present a description of the TMAP developed by General Dynamics and Unique Mobility, Inc.

APPROACH:

Discussion of vehicle's primary features, vehicle dimensions, energy source, electric drive train, and mobility characteristics.

LESSONS LEARNED:

The vehicle's primary features included composite monocoque body construction, hybrid diesel internal combustion and battery energy source, electric drive train, and highly robust mobility characteristics. The TMAP vehicle dimensions were 44.5" wide, 79.3" long, and 48.7" high. The energy source powering this vehicle consisted of a hybrid diesel-generator/battery combination providing electrical power to the all electric drive train. The diesel internal combustion engine and UNIQ alternator provided 5 kW of power at 28 VDC upon demand. Additionally silent operation and peak power capacity was made possible with the lead acid battery pack. The electric drive train consisted of two wheel mounted UNIQ electric motors with integral planetary gear reducers. This provided a clean, space efficient drive train solution with all the advantages of electric drive, including quiet operation, high efficiency, compact design, and excellent controllability. The TMAP vehicle's mobility characteristics were excellent, due to its low center of gravity, large diameter tires, and high power to weight ratio. The relatively compact size and low weight also allowed the vehicle to be transported easily in a minimum space. Initially designed for performance as a weapons platform the TMAP vehicle, or a vehicle of similar design, has the potential for missions as a forward observer, laser designator, or other light forces applications.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: MILESTONES, A Directory of Human Engineering Laboratory Publications, 1953 - 1986, January 1987
Author(s): Human Engineering Laboratory

OBJECTIVE:

MILESTONES is the cross-referenced directory of publications written by personnel of the U.S. Amy Human Engineering Laboratory and its contractors. It contains reports written from 1953 through the end of calendar year 1986. It should provide a convenient up-to-date index for other organizations and people working in the human factors engineering field.

APPROACH:

MILESTONES is comprised of three sections and is color coded to permit fast and easy access to information in specific areas of research. Section I (printed on white paper) lists the report by topic, Section II (yellow paper) lists them numerically and Section III (green paper) lists them by author.

LESSONS LEARNED:

Several HEL reports were identified as pertinent to the current UGV effort and are listed as follows:

Bauer, R. W., Auditory Localization of a Helicopter - From Ground Position, July 1963.
Bauer, R. W. and Blackmer, R. F., Auditory Localization of Noises, January 1965.
Bauer, R. W., Matuzsa, J. L., Blackmer, R. F., and Glucksberg, S., Noise Localization After Unilateral Attenuation, April 1966.
Hicks, S. A., Literature Review: Tracking Control Mechanisms and Displays (Light Antiaircraft System Oriented), December 1957.
Katchmar, L. T., Jelinek, R. E., and Hodge, D. C., Visual Efficiency Under Desert Conditions, 1956.
Wallach, H. C., Performance of a Pursuit Tracking Task with Different Delay Times Inserted Between the Control Mechanism and the Display Cursor, August 1961.
Moler, C. G. and Brown, G. L., Closed Circuit Television Vehicle Driving: 1. A Preliminary Investigation, August 1960.
Oatman, L. C., Target Detection Using Black-and-White Television Study I: The Effects of Resolution Degradation on Target Detection, July 1965.
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APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV Control Vehicle Power Requirement, 6 February 1987

Author(s): S. Martin

OBJECTIVE:

To present an estimate of the Tele-operated vehicle (TOV) control vehicle power requirements utilizing the latest information available.

APPROACH:

Present a breakdown of the control vehicle power utilization and the control station power consumption.

LESSONS LEARNED:

Three control stations - 633 watts each, one section leader station - 100 watts (estimate), lighting - 250 watts (estimate), environmental control unit (airflow) - 4,157 watts, instrumentation (VCR, etc.) - 53 watts (estimate), vehicle controls - 2 watts, Polhemus isotrak - 30 watts, two Westinghouse 1" CRTs w/remote elect. - 30 watts, two 9" COHU B&W CRTs - 90 watts, one joystick - 3 watts, two alpha-numeric display panels - 10 watts, video overlay - 10 watts, CS Processor - 350 watts, communications - 3 watts, and telemetry - 100 watts. The total TOV Control Vehicle power consumption is approximately 6,460 watts. Given this power requirement, a 10 Kwatt diesel generator has been selected to serve as the power source. The generator selected, a trailer mounted MEP-003A, is a Marine Corps inventory item which will provide the required three phase 60 hertz power. We must request one of these from the sponsor once we are positive the power estimates are sufficient.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV - Comms (Present Configuration), 15 June 1987

Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present the present cost and configuration for the TOV communication , power distribution, vehicle controls, and navigation systems.

APPROACH:

Discussed the present configuration, schedule, and cost of the following subsystems: communications, power distribution, vehicle controls, and navigation.

LESSONS LEARNED:

The budgets for the TOV subsystems were as follows: communications system - 12K (assuming GFE radios); power distribution system - 19K; vehicle controls - 31K; navigation system (Magnavox MX6102B Terrain Navigation Aid, UTM Grid Coordinates)- 48K.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Materiel Acquisition Handbook, AMC TRADOC, 1987

Author(s): Headquarters, U.S. Army Materiel Command, Headquarters, U.S. Army Training & Doctrine Command

OBJECTIVE:

This handbook describes policy, procedures, and responsibilities for initiating requirements, conducting research and development, and acquiring materiel items and systems to satisfy HQDA-approved requirements.

APPROACH:

This handbook begins with an overview of the Army Streamlined Acquisition Process (ASAP) using charts and text to describe phases and players, and referencing the following chapters to show their relationship within the overall process. Chapters 2 through 19 provide details on actions/practices necessary for successful implementation of the materiel acquisition process. Each chapter provides a general description of the subject area and AMC and TRADOC responsibilities, time constraints, and directives for the subject area. Additionally, when appropriate, chapters contain step-by-step narrative and flow-charted procedures for implementing a specific aspect of the materiel acquisition process.

LESSONS LEARNED:

The Concept Formulation Package (CFP) establishes technical and economic specifications to satisfy the stated requirement. It is prepared by TRADOC and AMC proponents or by a Special Task Force (STF) or a Special Study Group (SSG), formed for that purpose. The CFP consists of the Trade-Off Determination (TOD), Trade-Off Analysis (TOA), Best Technical Approach (BTA), and Cost and Operational Effectiveness Analysis (COEA) or an Abbreviated Analysis (AA). The TOD, TOA, and BTA are used to provide analytic rationale for, as well as technically document, the system concept(s) which are candidates to satisfy the requirement. The COEA is used to document the selection of the preferred candidate to meet the requirement based on cost and effectiveness. Definition of the BTA: A document prepared by the AMC MSC proponent assisted, as needed, by the TRADOC proponent that contains: 1) description of the best technical approach and ILS concepts based on the results of the TOD and TOA, 2) evidence that the proposed best technical approach is engineering rather than experimental, 3) estimated cost (RDTE, OMA, and MCA), total Army manpower requirements, procurement, and scheduling estimates, 4) recommendation on whether the development should be project managed, and 5) draft environmental impact statement.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: TOV - Things We Could Have Done Differently, 9 June 1988

Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present a list of technical problems encountered during the TOV project.

APPROACH:

Discussed problems encountered and possible solutions to these problems.

LESSONS LEARNED:

Technical problems identified during the TOV project were: 1) Lack of force reflection for vehicle brake and steering controls; 2) Lack of an adequate display system; 3) Need for an electrically powered head (or one that can be used with the vehicle engine off); 4) Need for faster turn-around with cable payout preparation; and 5) Problems related to head tracking using Polhemus Isotrack/3-SPACE Tracker systems. Several programmatic restrictions also constrained progress during the opening phases of GATERS. Among them, the need to conform to milspecs, the need to support multiple missions, the need for 3 CS's in a TOV system and the need for full day-night camera operation come to mind.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Simulator Sickness Field Manual Mod 3, August 1988

Author(s): Naval Training Systems Center Human Factors Division

OBJECTIVE:

To provide a description of simulator sickness, how to recognize simulator sickness, and how to treat simulator sickness.

APPROACH:

Discussion on symptoms of simulator sickness, who is vulnerable to simulator sickness, guidelines for preventing simulator sickness, engineering and maintenance guidelines, and instructor guidelines.

LESSONS LEARNED:

Simulator sickness is a form of motion sickness which sometimes occurs in simulators. It may be induced by either physical or visual motion, or by some unusual combination of these two sources of motion information. Symptoms of simulator sickness include: leaning, staggering, dizziness, confusion, disorientation, vertigo, drowsiness, fatigue, depression, apathy, eye strain, blurred vision, feelings of warmth, pallor, sweating, headache, fullness of head, vomiting, nausea, difficulty focusing eyes, stomach distress, burping, loss of appetite, difficulty concentrating, and visual flashbacks. Factors which may contribute to a crewmember's susceptibility are: hangover, sleep loss, flu, upper respiratory illness, head cold, medication, ear infection, ear blocks, upset stomach, and emotional stress. Maximum duration of a simulator flight should not exceed 2 hours, if possible. Take breaks, drink fluids, and use time-outs. Symptoms may occur immediately after a hop or sometime later. Be alert to any symptoms during the simulator flight debrief. If any occur, make sure the aircrew member has time to get over the symptoms before letting him/her leave. Make sure that the aircrew member is not suffering from vertigo before driving an automobile. For any severe problems such as vomiting, vertigo, or disorientation, see the flight surgeons immediately for help.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperated Vehicle System, Operator's Manual, Equipment Publication, Preliminary Draft, September 1988

Author(s): Naval Ocean Systems Center

OBJECTIVE:

This manual has been developed for the purpose of providing a description of the TOV system, instructions for effective use to include initial preparation for use, operation and operator level maintenance instructions.

APPROACH:

Discussion of general information, system equipment, and principles of operation; operating instructions including: operator/section leader stations; controls and indicators, operator CRT menu displays, pre-operation procedures, operation under usual conditions, post-operation procedures, operation under unusual conditions; and operator maintenance including: preventive maintenance checks and services, troubleshooting procedures, and unscheduled maintenance procedures.

LESSONS LEARNED:

The TOV system is composed of three remote vehicles (RVs) equipped with various mission modules, and a control van (CV) containing three operator control stations and a section leader station. The mobility sensors are comprised of either a pair of black and white image intensified cameras or a Fulinon Night Sight system; a pair of microphones; and a loudspeaker for broadcasting from the RV all mounted on a hydraulically powered pan/tilt platform which is controlled by the operator's head movements. The primary telemetry path between the RV and the operator control station is a fiber optic data link. The Magnavox MX 6102 Terrain Navigation System (TNS) uses dead reckoning as the primary means of position locating, with an accuracy of 3% of distance traveled. Periodically, the position location will be updated with satellite inputs, which are accurate to within 200 meters. The RV employs a diesel-fueled, quiet, portable mini-generator to recharge batteries that will provide power for operation of onboard systems and mission modules while the vehicle is operating in the quiet mode. The sensor platform (which is mounted on a hydraulically-powered mast) includes an infrared imager, a laser rangefinder or a rangefinder/designator, and a day/night 10 powered zoom lens (6x) camera.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperated Mobile All-Purpose Platform (TMAP) Instruction Manual, January 1989

Author(s): Martin Marietta Aero and Naval Systems

OBJECTIVE:

To provide a description of the TMAP operating systems and installation, operation, and maintenance procedures.

APPROACH:

Discussion of electrical and mechanical characteristics, installation procedures, operational procedures, and maintenance of system components.

LESSONS LEARNED:

Depth perception affected. Driving camera was color, charge coupled device with 52 degree FOV and auto iris. RISTA camera was B/W with 20 degree FOV variable focal length (25 mm to 250 mm) and magnification power up to 14 to 1. Five communication links were used.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: GATERS Test Results, 6 March 1989

Author(s): C. W. Graham

OBJECTIVE:

The objective of this test was to find out the maximum ambient temperature that the electronic and hydraulic components currently on the Remote Vehicle (RV 2), HMMWV #544902 can operate under up to a limit of 120 degrees Fahrenheit.

APPROACH:

Discussion of results, recommendations, apparatus, test preparations, temperature test procedures, preoperative checkout results, and vehicle operational checkout procedure.

LESSONS LEARNED:

At the 100 deg F nominal test temperature everything worked except for the Emergency Abort System. When the red button was pushed on the Control Station the engine did not shut off and the emergency brake was not applied. Back at ambient temperatures the EAS system functioned normally. This problem was traced to a leaky tantalum capacitor on the EAS card in the Vehicle Control ATR Cabinet. This leaky tantalum capacitor was replaced with a ceramic capacitor of smaller value. When the whole circuit board was tested with a heat gun the engine did shut down when the EAS button was pressed. With the new capacitor installed, the 110 deg F nominal temperature test was conducted. Again everything worked except for the EAS system and one video channel. This time the EAS system shut the engine down but did not apply the emergency brake. By monitoring the digital display on the EAS card in the Control Station it was apparent that no EAS feedback signal was coming from the Remote Vehicle. This and the fact that the EAS system did not apply the brake when the vehicle was retested at ambient temperature indicates that the EAS microprocessor system on the remote vehicle permanently failed during the temperature test. The engine also began missing, coughing and sputtering every second or so at this temperature. Since the WAIT light on the dashboard blinked in synchronization with the engine missing it looks like the RUN signal to the engine was becoming intermittent at 110 deg F. When the nominal 120 deg F temperature test was conducted no new problems other than those uncovered in the 110 deg F test occurred.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Test Status Report, 20 May 1989

Author(s): G. S. Hall

OBJECTIVE:

To present the results of testing the TOV #1 from 8 - 20 May 1989.

APPROACH:

Discussion of significant events, significant problems, conclusions, and recommendations.

LESSONS LEARNED:

To get longer lengths of cable, two and three short pieces of fiber optic cable were spliced together using both FC type connectors and the ST type. Results were generally good. On 10 May 1989, during a mission, a tank crossed the cable without causing so much as a flicker of the video. On 11 May 1989, a "bridge builder" truck crossed the cable without causing link degradation. Mobility video was realigned to near infinity vs 18 feet. This gives better stereo vision for greater distance, but causes difficulty with focusing in the cockpit of the RV. On 9 May 1989, Capt Murray, being intimately familiar with the terrain at the test site, drove remotely to determine course safety. At one point, even though there was no video indication and the safety observers could not detect it, he nearly drove off about an 8 foot drop-off. Had he not been aware of its presence from previous experience, results would have been hazardous. This pointed out just how crucial stere video is to the system. Video has been recorded showing how deceptive determination of the horizon can be. Since the mobility cameras use the vehicle as its "horizontal" frame of reference, and since peripheral vision is limited, it is not always possible for the driver to determine whether he is going uphill or downhill as opposed to being level. One video tape records the vehicle on an apparently level road; when the eyes are elevated, however, the ocean in the horizon is seen to be tilted almost 30 degrees! An inclinometer was installed above the steering wheel, visible to the operator, as a short term solution.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: UGV/TOV FY 89 3rd Quarter Review, 19-20 June 1989
Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present a description of the UGV/TOV system as of 19/20 June 1989.

APPROACH:

Discussion of the TOV program approach and objectives, UGV/TOV RV base vehicle, RV vehicle controls, mobility sensor system, navigation system, vehicle navigation aid system (VNAS), power distribution system, emergency abort system, RV processor system, RV mission module interface, telemetry interface/processor, CS vehicle control, head tracker, CS processor system, control vehicle/shelter, control station/section leader station, communications system, control vehicle power system, TOV video - block diagram, electro-optics telemetry, telemetry trouble shooting results, comparison of possible command/data links, fiber optic command/data link, fiber optic connectors, cable handling, observation/surveillance mission module, laser designator test results, mission module processor, system builders tests, NOSC UGV/TOV organization, and the "Early User" test team.

LESSONS LEARNED:

The RV base vehicle (M998) has the following characteristics: 6,400 lbs gross weight; 3,400 lbs payload; 55 mph hwy, 20 mph offroad; and 300 mile range. Vehicle additions/modifications include: heavy duty suspension, windshield and rollbar removed, doors cut off at windows, alternator dual charge path, aux battery pack, 2nd hydraulic pump coupled w/crankshaft, and replaced throttle return spring. The VNAS equipment takes 380 cubic inches of space, weighs 1.5 lbs, and uses 63 watts on the RV and takes 90 cubic inches, weighs 3.3 lbs, and uses 7 watts on the CS. Telemetry trouble shooting results: Eliminated ghosting on all video channels by properly terminating the video filter; reduced channel-to-channel cross talk and noise in one video channel by improving circuit board layout; corrected channel video degradation on TOV #1 by replacing video selector board (possible component failure); and regained camera syncs on TOV #2 by replacing line driver (component failure). RG 174 Coax Cable: 1 Equivalent Video Channel, 400 Equivalent Voice Channels, 4 MHz BW, 70 dB/km attenuation, 1 km unrepeatered distance, 5 mm size, RV electronics cost $15 K, and 30 km of cable costs $15 K. Radio (Microwave RF): 2 Equivalent Video Channel, 500 Equivalent Voice Channels, 6 MHz BW, 30 km unrepeatered distance (unobstructed line of sight), RV electronics cost $150 K. Single Mode Fiber Optic Cable: 5 Digital Equivalent Video Channel, 16,000 Equivalent Voice Channels, 100 GHz-Km BW, 0.25 dB/km attenuation, 100 km unrepeatered distance, 2.1 mm size, RV electronics cost $15 K, and 30 km of cable costs $33 K.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperated Vehicle (TOV) Program Joint Teleoperated Vehicle (JTV) Demonstration, Demonstration Report, 31 October 1989

Author(s): SEACO, A Division of Science Applications International Corporation

OBJECTIVE:

This document is a report of the Joint Teleoperated Vehicle Demonstration that was conducted at USMC facility Camp Pendleton, Ca., on 20 September 1989.

APPROACH:

Discussion of demonstration preparations, rehearsals, and demonstration results.

LESSONS LEARNED:

The first and foremost problem was the weakness of the fiber-optic cable, which failed several times. The cable broke when run over by a vehicle, was severed by a piece of shrapnel, and snapped when it was not wound correctly. A related problem with the fiber-optic cable is the connectors. They are fragile, and one was responsible for the cable failure during the first rehearsal. Loss of contact with the vehicle can be expected on a regular basis if the cable is not strengthened. A backup means of communication between the control station (CS) and remote vehicle (RV) needs to be developed in case of cable failure. Currently radio is being proposed as the alternative, however, it would defeat several purposes of the TOV, which include: providing surveillance around hills and obstacles, establishing an unjammable remote presence in a forward area, and implementing surveillance with a low possibility of electronic detection. Once the cable problem was fixed, another problem arose. The target was west of the TMAP position, and the sun was low on the horizon. As a result, the camera on the TMAP could not "see" the laser spot on the target, since it was "blinded" by overexposure to the direct sun. The laser designator could only be positioned from the tent where a special filter on an observation camera could detect the laser spot. The camera personnel in the tent then provided directions to TMAP designator operator until the spot was on target. The laser range finder on the TOV also experienced sensitivity to temperature and did not function at high temperatures. The addition of peripheral vision capabilities would greatly enhance the remote presence feeling. The operator of the TOV was found to have trouble determining the situation of the vehicle, e.g., if it is in a ditch, or positioned at an angle to the plane of gravity, or if there is something in the way of the vehicle that is not visible to mobility cameras.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Automating Dan'l Boone, December 1989

Author(s): Yale Jay Lubkin

OBJECTIVE:

To present a discussion of the JPO effort to develop remotely controlled combat reconnaissance vehicles.

APPROACH:

Discussed the problems associated with the TMAP and the TOV systems.

LESSONS LEARNED:

The TOV is too big and vulnerable to be an effective recon vehicle. It can do 55 mph on the highway and 20 mph off the road. The TOV can be operated either remotely or with a human driver. The TOV has a payload, 3400 lbs, big enough to let it carry highly offensive weapons, like the Hellfire and a .50 cal heavy machine gun. Stereo vision is provided by two TV cameras mounted on a scissors mount, and the cameras can traverse a full circle. But an enemy armed with just about anything that shoots can quickly put it out of action, and it is really much too large to do anything covertly. The TMAPs have two glaring problems: 1) their speeds are low. Design speed for cross-country is 10 Km/hr, which is much slower than a man can run. A single soldier can track a TMAP and put it out of commission without ever being seen by the operator. He can see the TV camera pointing, and just arrange to be invisible when the camera points in his direction. They need omnidirectional short range vision, and weaponry to match.; 2) they are tied to a fiber-optic cable. They have RF links, but these are jammable. If the frequency is high, then the system is restricted to line-of-sight. If the frequency is low enough to avoid line-of-sight problems, then the transmitter interferes with the thousand other low frequency channels which will be operating in wartime. Either way, the radio link is a beacon to a homing missile, and easy to intercept or jam. The fiber optic link is a very weak point. Fiber cable is limited to about 30 Km to a spool, and this is the total travel permitted to the TMAP. That means back and forth and around trees. The cable can snag and break. It will be cut by rocks or gravel. And if shooting is going on, shrapnel is almost certain to cut the cable. There is also the risk of hostile Indians cutting the cable with their little hatchets just for the fun of it. There is a solution to the communications problem which is not radio, needs no cable, and is not restricted by line-of-sight.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperated Vehicle (TOV) Program, Concept of Employment (COE), White Paper, December 1989

Author(s): SEACO, A Division of Science Applications International Corporation

OBJECTIVE:

To identify broad operational and organizational concepts for the employment of a unmanned ground vehicle (UGV) system that is based on current UGV technology.

APPROACH:

Discussion of mission, threat, description, organizational concept, concept of employment for the Remote Vehicle (RV) and the Control Van (CV), other operational considerations, and manpower requirements.

LESSONS LEARNED:

UGV missions include reconnaissance, surveillance, direct fire, target acquisition, control of supporting arms, and NBC reconnaissance and monitoring. Other missions such as mine detection and clearing may be added when suitable detection devices have been developed. UGV systems can perform hazardous battlefield functions efficiently, provide more economy of manpower, reduce casualties, and act as a force multiplier.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Critical Technology Issues for FY90 UGV Robotics Master Plan, 1990
Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present a list of technologies that should be addressed in the Unmanned Ground Vehicle (UGV) FY90 Robotics Master Plan.

APPROACH:

Discussion of Near Term Critical Technology Issues, Long Term Technology Issues, and Strengths and Weaknesses of the TMAP and TOV.

LESSONS LEARNED:

TMAP strengths: real time man-in-the-loop or teleoperated; color driving video sensor; low light level video camera for night driving; digitized map display in Grumman TMAP; light weight composite structure; quiet diesel electric drive in Grumman; operates in close quarters in trees and brush; and redundant data links. TMAP weaknesses: extremely slow (maximum speed 8 km/hr or 5 mph); hard to control in straight line at maximum speed; lacks stereo vision display; vision field of view limited; nav system has not proven to be reliable; digitized map limited by map data base available; new platform; no logistics, maintenance, training pipeline; not easily adapted to multiple missions; capable of only light weight mission payloads; extremely noisy diesel engine in Martin TMAP; high cost special design fiber optic link; RF link requires rework to be reliable; only vision feedbacks to support teleoperation; joystick control limits driving at maximum speed; poor system reliability; not capable of sustained user operations; and does not meet rough terrain specifications. TOV strengths: high speed (55 mph on road, 20 mph off road); 30 km remote operation range; remote driving controls duplicate normal vehicle; mobility vision system coupled to operator head motion; helmet mounted driving displays to give operator feel of being in vehicle; control van with 3 control stations, for multiple remote vehicle operations; suitcase controller for single vehicle operation; standard command and control net access; section leader control of all vehicle operators; satellite navigation with dead reckoning; military UTM grid coordinate display system; HMMWV currently in inventory; logistics and maintenance program established; capable of heavy payloads; teleoperation capability scalable to any size platform; fiber optic command/data link, 30 km long; RF safety abort command link; resistant to most field damage conditions; tested for rollover by tire and tracked vehicles; color video camera with 10/1 zoom for day; thermal imager for night and smoke conditions; acoustic detection; target ranging/designation; sensors mounted on extendable mast, with 360 degree pan at high and low speed rates; and target viewing from defilade over 10 ft. obstacle. TOV weaknesses: mobility sensor powered by hydraulics; control van considered cumbersome for field ops; not transportable by helicopter; current design of head mounted displays are heavy; HMMWV considered too big for present requirements; does not maneuver in wooded terrain well; and no RF backup.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Analysis and Concepts for Unmanned Weapon Systems Development of the Teleoperated Mobile Anti Armor Platform, January 1990

Author(s): Virginia Young

OBJECTIVE:

This report details the programmatics and the development of a system that was originally targeted to perform anti-armor missions that would allow for weapon enhancements to improve lethality and probability of kill for several existing missile systems.

APPROACH:

Discussion of the original concept formulation, research and development process, requirements, program development, contractual efforts, and conclusions.

LESSONS LEARNED:

Near-term technology will support defensive missions only in remotely operated configurations. Long-range high-speed dynamic operations are not state-of-the-art. Near-term vehicles must be simple, small, lightweight, easy to operate, and inexpensive. Robotic features for the near term will be limited to relatively simple operations such as slow movement over familial paths, detection of moving targets for operator cueing, and preplanned actions.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: CALEB Design Features, 3 January 1990

Author(s): Elizabeth S. Redden

OBJECTIVE:

To summarize the results of interviews with two Tactical Multipurpose Automated Platform (TMAP) instructor/operators.

APPROACH:

Discussion on the Driving Video System, Targeting Video System, CRT Display, Navigational System Display, Controls, Pan/Tilt Control, Operator Control Unit (OCU), and Mobility Base Unit (MBU).

LESSONS LEARNED:

A color camera is preferred to black and white because it: 1) adds more realism, 2) permits faster and better target identification, 3) provides more definition, and 4) heightens awareness of surroundings. Depth perception is better with color systems. The ability to detect, recognize and identify targets out to 1000 meters is not a problem for either the Grumman or the Martin Marietta systems. The systems are so low to the ground that false readings sometimes occur because of vegetation in the path of the range finder. The RF link is reliable only when line of sight between the operator console and the vehicle is maintained. The fiber optic link provides a clear picture but is vulnerable to breakage and has a limited range. The Martin Marietta's skid steer is more difficult to learn. The system is hard to control with the joystick. The size and weight of the Grumman OCU is considered excessive by both interview subjects. The Martin Marietta system consists of too many separate components to be portable. Recommend that the OCU have built in retractable or stowable legs for out of vehicle operations and that a lightweight portable chair or stool be provided for out of vehicle operations. The length of time one man can continuously operate the system depends upon the mission. For missions involving a lot of movement or for missions while the operator is in MOPP4 conditions, the time should be reduced. Both interview subjects felt that 4 hours should be the maximum time for intensive missions. (One subject stated that one operator could manage an 8 hour shift if it was primarily surveillance without much movement involved.) He further stated that times should be reduced by 50% for MOPP4 conditions. Operator feedback problems identified were depth perception and judging slope angles. The Martin Marietta system's inclinometer helps judge slopes.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: UGV/TOV In-Process Review, FY 89 4th Quarter, FY 90 1st Quarter, 8 January 1990
Author(s): Naval Ocean Systems Center

OBJECTIVE:

To present a description of the UGV/TOV system as of 8 January 1990.

APPROACH:

Discussion of the TOV program objective, TOV system, control station, lessons learned/upgrades required, mobility sensor system, helmet-mounted display system, fiber optic command/data link, cable bend loss test, section leader/data acquisition systems, communications system, observation/surveillance mast, observation/surveillance sensor suite, TOV demo for 5th Marines, RSTA demo 1st Marine, testbed vehicles, UGV/TOC, control station options, vision display alternatives, night vision sensor, and UGV/TOC tradeoff studies - NOSC areas.

LESSONS LEARNED:

The remote vehicle is a HMMWV (M998 series) which has the following: 80 km/hr hwy, 35 km/hr offroad; day ops - night upgrade available; head coupled stereo vision and binaural acoustic sensors; nav in military grid coordinates. The reconnaissance/surveillance/target acquisition module has the following: extended mast; Cohu Model 4800 B&W video with 10:1 zoom (daylight); AN/TAS 4A thermal imager (smoke/night); AN/PAQ 3 Mule laser ranger/designator; and ADS acoustic sensor. This suite has a total weight of 174 lbs. The weapon pedestal has the following: ground-launched Hellfire missile; and M2 heavy machine gun. Visual vs vestibular conflict causes nausea effects. Improved feedbacks (road noise, accelerations, wind in force) could reduce this conflict. Color vision is preferred over B&W. Cyclops (NFOV) on demand will improve "down road" vision. Stereo required for close-in obstacles/holes avoidance. Awareness of vehicle situation requires "seat of pants" or visual indication of attitude. FO cable vulnerable to high-speed rollovers by wheeled vehicles and to shrapnel. Field splicing FO cable is mandatory. Higher resolution, color vision system approaching 1000-line NTSC preferred. Extendable scissors lift stable at maximum extension in the wind (can use at variable heights from 6 to 12 feet above ground). Laser beam jitter 180 microradians. Laser designation out to 2 km. The mobility sensor system features/capabilities: 1) pan: +/- 185 °, 120°/s, 240°/s^2; 2) tilt: +/- 45°; 3) hydraulically powered; 4) Cohu 4800 CCD stereo TV camera pair; 5) 2.75 inch separation; 6) 30 feet convergence; 7) full overlap at convergence; 8) 40 degrees FOV; 9) 500 TVL horizontal, 350 TVL vertical; 10) 1 lux to bright light; 11) binaural acoustic sensors; 12) 50-12000 Hz frequency range; 13) 15 db. - 146 db. dynamic range; and 14) artificial pinnas.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Operational and Organizational Plan: Tactical Unmanned Ground Vehicle (CALEB), Final Draft, 21 February 1990

Author(s): U.S. Army Training and Doctrine Command, U.S. Army Infantry School

OBJECTIVE:

To provide a description of the operational characteristics of Tactical Unmanned Ground Vehicle (CALEB).

APPROACH:

Discussion of the need for, the threat to be countered by, the survivability of, the sensing capabilities of, the mobility/transportability characteristics of, the command/control issues, the operational plan, the organizational plan, the logistics/maintenance concepts, the manprint issues, the communication systems, the navigation systems, and standardization/interoperability/commonality issues of the Caleb.

LESSONS LEARNED:

Deficiencies defined by the 1989 TRADOC BDP are: 1) Inadequate capability to locate targets during periods of limited or obscured visibility, 2) Inadequate capability to collect threat information - IEW/HUMINT, 3) Inadequate capability to locate targets beyond line-of-sight, 4) Inadequate capability to operate in NBC conditions, 5) Inadequate capability to collect/process threat information in the rear area, 6) Inadequate capability of dismounted forces to attack a heavy threat, 7) Inadequate capability to detect NBC hazards, 8) Inadequate capability to strategically deploy critical systems of contingency forces, 9) Inadequate capability of infantry forces to attack targets in urban areas, 10) Inadequate capability to provide physical security for rear area units, 11) Inadequate capability to conduct deception operations, and 12) Inadequate capability to conduct Battlefield Circulation Control (BCC). In the passive mode, the Caleb will be audibly nondetectable by a soldier within 10 meters. When moving, the Caleb will be audibly nondetectable by a soldier at a distance of 100 meters. The Caleb will be capable of being driven and operated during the day and periods of limited visibility, with an operating radius of 4km(required)/10km(desired) from the operator's remote position. Funding implications: 1) Quantity - 5,069 Calebs, 2) RDTE - $29,000 each Caleb, 3) Procurement Cost - $129,000 each Caleb, 4) Unit Cost - $100,000 each Caleb, and Life Cycle - $1.2 Billion.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperated Vehicle (TOV) Program, Revised Required Operational Capability (ROC) for Unmanned Ground Vehicles, Final Draft, 26 February 1990

Author(s): SEACO, A Division of Science Applications International Corporation

OBJECTIVE:

To review the Draft Required Operational Capability (ROC) for the Unmanned Ground Vehicle (UGV) System to provide alternative concepts for consideration in further UGV development.

APPROACH:

Review the draft ROC and compare its provisions with the TOV Program Concept of Employment (COE) White Paper of December 1989, the U.S. Army Operational and Organizational (O&O) Plan for Tactical Unmanned Ground Vehicle (Caleb) dated 27 November 1989, and the ROC description outlined in MCO P5000.10. Prepare recommended additions, deletions, or other changes and include these within the draft ROC as lined-out deletions, underlined inserts, and rationale statements that explain the proposed change. Publish a Required Operational Capability for the UGV with two attachments. Attachment A will contain the Draft Marine Corps UGV ROC in its final iteration, amended to show deletions, inserts, and rationale, and Attachment B will contain a "clean" version of the proposed UGV ROC, with the lined-out deletions, underlined inserts, and rationale statements deleted.

LESSONS LEARNED:

Mission profiles include reconnaissance/surveillance, direct fire, target location and control of supporting arms, and NBC reconnaissance and monitoring. The Mobile Base Unit (MBU) must precede or accompany mechanized, motorized, or dismounted forces in offensive operations. The UGV video system will be stereoscopic and will function under both day or night conditions. MBU must be as small as possible, with consideration for the various mission modules and the need for mobility. Operational range of the MBU will be 30 km required and 50 km desired. The UGV will be considered expendable when employed in high risk, hostile environments, and therefore will possess no armor protection against enemy fire.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Broad Area Announcement for Development of Remotely Controlled Systems for a Surrogate Teleoperated Vehicle, 10 May 1990

Author(s): Naval Ocean Systems Center

OBJECTIVE:

To solicit the participation of all offerers capable of meeting the needs defined in the Broad Area Announcement.

APPROACH:

Discussion of general system features, desirable system features, and required system features.

LESSONS LEARNED:

Servo-controls backdrivable allowing manual operation. Desirable features: maximum size - 5.5 ft width x 5.5 ft height x 13 ft length; 5500 lbs gross weight; quiet muffled diesel engine; automatic transmission; 250 miles range; 35 mph on improved roads, 25 mph off-road terrain, and 15 mph climbing 60% grade; traverse 40% side slope; ford/swim 2 ft deep water; minimum payload 800 lbs; extendable mast; platform motion range +/- 45 degree tilt on +/- 180 degree pan; Mobility Sensor Suite: video camera pair, each 40-60 degree field-of-view overlapped for stereo, stereo alignment and lock capability, high resolution solid state imagers, image stabilization, auto iris control, bloom and smear resistance, RS-170A output, mounts for camera pair with night vision lenses; triaural (3 sensor) acoustic detection system, 30hz -20hz response, 60 db dynamic range, balanced binaural output; GPS with dead reckoning and SATNAV or inertial navigation backup, 8 digit GPS and 6 digit backup accuracy, remote platform speed, heading, position (UTM grid coordinates) in RS-422 format; RSTA Sensor Suite: color video camera, 14:1 zoom lens or switched wide (40-45 degree) to narrow field-of-view, high resolution solid state imager, bloom and streak resistance, auto iris control, RS-170A output, mount for camera with night vision lens; FLIR viewer (8-12 micron spectral band) or mount for GFE system (AN/TAS-4A), RS-170A output; Laser ranger/designator or mount for GFE system (Opto-Electronics LTM-86), RS-170A for sight camera, calculated target position in milgrid. Required features: operation in temp range 0-50 degrees C, in rain, snow, dust, over paved/secondary roads, off-road (est 20 g shock and vibration), in all soil types and 2 ft deep water.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Sandia's Security-To-Go, June 1990

Author(s): Tech News, Mechanical Engineering

OBJECTIVE:

To discuss Sandia National Laboratory's versatile security system.

APPROACH:

Discussion of the Thomas.

LESSONS LEARNED:

The remote security system, which consists of an unmanned portable sensor station, a radio-controlled reconnaissance vehicle, and an integrated control console, can be used in situations where more permanent security systems are impractical. The portable sensor station, which is small enough to be transported in a pickup truck, is equipped with intrusion sensors that can transmit data to an operator located at a control console more than a mile away. It is equipped with a passive infrared motion sensor, video camera, near-infrared spotlight, ground surveillance radar, and four microphones. Also included are weather sensors that measure wind speed, temperature, light level, and precipitation. The sensors are mounted on a platform that can tilt and revolve to adjust to the field of view. The sensor station is augmented by a roving reconnaissance vehicle that can carry video cameras and sensors to areas obscured by trees and brush. The radio-controlled vehicle, called Thomas (for telemanaged mobile security station), is based on a Honda 350 four-wheel-drive, all-terrain vehicle. Thomas's cameras and sensors are mounted on a pneumatic mast that can be raised 10 ft above ground level.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Surrogate Teleoperated Vehicle, Technical Proposal, 30 July 1990
Author(s): Robotic Systems Technology, Division of F & M Machine Corporation

OBJECTIVE:

To provide a technical description of the proposed surrogate teleoperated vehicle (STV) with discussion on the mobile base unit, operator control unit, communication links, and RISTA mission module; including rationale for major component choices along with explanations of how each choice relates to requirements in the Army Operational & Organizational (O&O) Plan and the Marine Corps Initial Statement Of Requirement (ISOR) or lessons learned from past unmanned vehicle experience (i. e. TMAP and TOV).

APPROACH:

Discussion of the technical objectives, technical concepts, technical approach, scope of proposal, subcontractors/teaming, management organization, personnel qualifications, place and period of performance, special considerations, security clearance, and additional hardware options. The STV program was broken down into four distinct phases to analyze potential schedule slips and cost overruns: the initial design effort, material ordering, system integration, and assembly and testing of units.

LESSONS LEARNED:

The mechanical failures in the TMAP chassis were due to the use of a one-of-a-kind, custom chassis; STV uses a proven chassis. The lack of a true suspension on the TMAP limited the vehicle speed to 7 - 8 mph; the STV uses a proven suspension system. The TMAP used skid-steering which was awkward to safely operate remotely and was difficult and expensive to electronically control; the STV uses Ackerman steering. The four-wheel vehicle used for the TMAP lacked adequate size and all terrain mobility; the STV uses the largest platform that will fit in the bed of a HMMWV and a six-wheel drive platform to provide maximum rough and all terrain mobility. The STV uses a scissors type (rectangular pantograph) mast design. Based on TMAP test results at Sandia National Laboratory and 29 Palms and the IR&D HMMWV testbed, the STV uses the maximum stereo resolution currently commercially available in an NTSC format. The TMAP used a black and white camera with an image intensifier for daytime driving and targeting which reduced resolution and degraded the image considerably; the STV uses four separate camera mounts to allow simultaneous use of both day and night targeting and driving cameras. The STV uses a high resolution color targeting camera for improved target detection in cluttered or constant color scenes. The STV ADS system provides true 360 binaural hearing with three pairs of microphones and the capability to perform electronic beamforming to mimic the rotation ability of the human head. STV uses the TMAP navigation system approach.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Tra le-Off Determination, United State Army Tactical Unmanned Ground Vehicle (Caleb) and United States Marine Corps Unmanned Ground Vehicle (UGV), Volume I, Introduction, Concepts, Analysis, Conclusions, 28 September 1990

Author(s): U. S. Army Material Command

OBJECTIVE:

This Trade-Off Determination (TOD) was prepared for the U.S. Army Infantry School (USAIS), the U.S. Marine Corps Combat Development Command (USMCCDC), and the Joint Project Manager for Unmanned Ground Vehicles (UGV). The purpose of the TOD was to provide information on ranges of materiel options available to address existing battlefield deficiencies. The U.S. Army Draft Operational and Organizational (O&O) Plan and the U.S. Marine Corps Draft Required Operational Characteristics (ROC) define the deficiencies. The report addresses the relationships between performance, physical characteristics, procurement cost, availability, supportability, and risk.

APPROACH:

Descriptions of plausible technical approaches or concepts including modifying existing materiel and using non-developmental items (NDI) were provided. Viable future or evolving technologies and materiels were addressed as possible preplanned product improvements (P^3I). The core of the TOD describes key trade-off relationships between alternate approaches and the relationship of peroformance characteristics. Bands of performance were defined in an effort to provide general guidance to the Trade-Off Analysis (TOA) rather than providing detailed design trade-offs. Estimates of acquisition costs, plans, and schedules were included. Technical approaches were recommended. However, these approaches are not specific hardware solutions, but solutions representing a particular technology.

LESSCNS LEARNED:

The majority of the subsystems, (which provide the desired performance), require militarization or ruggedization. Two critical trade-off areas for the combat developers are mobility versus transportability and cost versus mission. Based on mobility, transportability, and safety factors, the Mobile Base Unit (MBU) should not exceed about 6.5 feet in length, 5.5 feet in width, 5.0 feet in height, and 1.0 ton in weight.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trade-Off Determination, United State Army Tactical Unmanned Ground Vehicle (Caleb) and United States Marine Corps Unmanned Ground Vehicle (UGV), Volume II, Appendices, 28 September 1990

Author(s): U. S. Army Material Command

OBJECTIVE:

To provide a listing of references used in the TOD, Volume I.

APPROACH:

The U.S. Army O&O, the Operational Mode Summary/Mission Profile, the Rationale Annex, the Coordination Annex, the Operational Concept, the U.S. Marine Corps ROC, the TOA Study Plan, and a Market Survey is included in this report. Additional sources included were a listing of Contributors, MBU Support Documents, OCU Support Documents, RSTA/Driving Module Support Documents, Communication Data Link Support Documents, Navigation System Support Documents, TOD Joint Working Group Minutes, ILS Support Documents, MANPRINT Support Documents, Cost Support Documents, and RAM Support Documents.

LESSONS LEARNED:

The most promising platforms for the MBU are commercial grade, multiple wheel drive ATVs. The 6x6 amphibious wheeled/track convertible chassis appears to offer a good compromise of capabilities. If amphibious capability can be left off, a suspended multiple wheel drive ATV is recommended. It was determined that the portable concept (<40 lbs) does not have enough spare weight to provide radio communication and thus can only accomodate fiber-optic communication. The OCU will most likely be a two or three piece, 100 pound unit unless radio communications are avoided. For RISTA, recommend the AN/TAS4-A type FLIR. For driving, recommend an AN/VVS-2 type image intensified viewer coupled to a high resolution balck and white camera. For daylight viewing, recommend a high resolution color video system. For navigation, recommend a hybrid navigation system that integrates an inertial based Vehicle Navigation Aid System (VNAS) and a global positioning system.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Operational and Organizational (O&O) Plan for the Tactical Unmanned Ground Vehicle (TUGV), 30 November 1990

Author(s): U.S. Army Training and Doctrine Command (TRADOC)

OBJECTIVE:

To provide a description of the operational characteristics of Tactical Unmanned Ground Vehicle (TUGV).

APPROACH:

Discussion of the need for, the threat to be countered by, the survivability of, the sensing capabilities of, the mobility/transportability characteristics of, the command/control issues, the operational plan, the organizational plan, the logistics/maintenance concepts, the manprint issues, the communication systems, the navigation systems, and standardization/interoperability/commonality issues of the TUGV.

LESSONS LEARNED:

TUGV is vulnerable to threat weapons from small arms to heavier weapons/mines. A TUGV using radio control will be vulnerable to radio electronic combat. TUGV is also likely to be subjected to the effects of NBC, directed-energy weapons, obscurants, and Electromagnetic Pulse (EMP). TUGV will operate during day, night, and periods of limited visibility, and have an operational range of up to ten kilometers from the operator. It should also be capable of transporting the operator and his individual equipment within the unit area of operations. TUGV should have features which allow for automatic stop, and permit the operator to locate the remote system in the event the command/communications link is interrupted or lost. TUGV will employ an onboard Position/Navigation capability that will provide grid location and heading information. The TUGV should be survivable against small arms/artillery fragmentations to at least the level of the soldier for which it surrogates. The TUGV should be able to conduct its remote mission for 12 to 14 hours, including travel time to and from the operator's location, while operating non line-of-sight from the operator. The TUGV should provide the operator with the capability to view the target area from behind obstacles 5 meters or more in height. During static operations the TUGV should permit the operator to control 1 moving system, while monitoring 3 other systems. Funding implications: 1) RDTE - 100 - 200M, 2) Procurement Cost - 250 - 500M, 3) Unit Cost - 100 - 200K, and 4) Life Cycle - 1 - 2 Billion.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Initial Statement of Requirement (ISOR) for an Unmanned Ground Vehicle (UGV) System, 26 December 1990

Author(s): U.S. Marine Corps

OBJECTIVE:

To provide a description of the operational characteristics of an Unmanned Ground Vehicle (UGV).

APPROACH:

Discussion of the need for, the threat to be countered by, the survivability of, the sensing capabilities of, the mobility/transportability characteristics of, the command/control issues, the operational plan, the organizational plan, the logistics/maintenance concepts, the manprint issues, the communication systems, the navigation systems, and standardization/interoperability/commonality issues of the UGV.

LESSONS LEARNED:

The UGV will be employed in direct support of individual infantry battalions, separate battalions and the artillery regiment of the Marine Division. Some of the missions that the UGV will be able to perform are as follows: 1) Reconnaissance/surveillance, 2) Direct fire, 3) Target location and control of supporting arms, and 4) NBC reconnaissance and monitoring. When fully equipped, the vehicle platform must meet the following requirements: 1) unmanned operation speed of 15 mph (24.15 km), 10 mph off-road, rough terrain, 2) if manned or loaded in a vehicle or trailer, able to achieve convoy speeds of 35 mph (56.35 km), 25 mph (40.25 km) off-road, rough terrain, 3) must be capable of operating in rain, snow, ice, military standard sprays, mud, sand, and all soil types, and 4) acoustical sensors must allow normal human sound localization capabilities at the remote site. The Reconnaissance/Surveillance Mission Module must perform the following tasks: 1) 360 degree/6400 mils optical scan in both manual and automatic operational modes, 2) detect, acquire, and identify vehicular targets at 2 km and personnel targets at 1 km under all lighting conditions with an accuracy of 0.90, and 3) determine the position of the remote platform relative to the control station with an accuracy of +/- 10 meters. Laser designation of targets for passive laser guided munitions. Provide secure, non-jammable communication when the remote platform is beyond the line-of-sight of the control station. The UGV will have a working radius of 10 km (30 km desired).

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: CDRL A0013, Contract Summary Report (Demonstration Report), 15 February 1991

Author(s): Scott Endo and Douglas Will

OBJECTIVE:

To present the results obtained from testing performed at Twenty-nine Palms, Camp Wilson.

APPROACH:

Provided a description of the demonstration, attendee observations/reactions, and problems/resolutions.

LESSONS LEARNED:

Due to the highly mobile nature of the exercise, the terrain over which the vehicle was to be driven could not be previewed beforehand. Despite this fact, however, off-road remote driving and surveillance maneuvers were accomplished in conjunction with Marine ground forces deployed on the target range. Night surveillance capability was also successfully demonstrated. Constructive comments from the 1/9 Marines staff included the following: They would like to see a night driving capability (as well as surveillance) for the TOV. Their drivers are currently utilizing PVUS goggles on a regular basis to maneuver at night. The use of fiber optic cable was thought to be a drawback since it could easily be cut and had to be retrieved following the exercise. (The counter argument in favor of fiber optic cable is that it provides for secure communications, is extremely durable despite its appearance, and would be expendable under actual combat conditions). The Communications Drawer in the Control van still has various problems which have existed since the September '89 demo and after a more recent rewiring. A major troubleshooting effort will be required to get all of the communication channels working for full operator and supervisor communications capabilities. As mentioned in the 15 February 1991 Status Report, the Magnavox Navigator seems to have lost its auto start capability and is incapable of locating a satellite. The dealer may have to be contacted to resolve this problem.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Memorandum for Record: BTA Input, 19 February 1991

Author(s): BTA Team

OBJECTIVE:

To consolidate and document questions and comments pertaining to the formulation of the Best Technical Approach (BTA) for the Unmanned Ground Vehicle (UGV) program.

APPROACH:

The memorandum was divided into the following categories: overall system questions (mission scenario questions and operational/mission outline), man/machine interface problems, logistics questions, MANPRINT/operator requirements problems, command and control questions, specific sub-component questions (mobile base unit, operator control unit, communications links, payloads), and specific trade-off analysis requirements.

LESSONS LEARNED:

Clear understanding of the mission objectives must be finalized, human factors and/or degree of man/machine interface must be analyzed and optimized, and a comparison of system, cost, and risk relative to mission must be performed.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: CDRL A0013, Contract Summary Report (Demonstration Report), 26 March 1991

Author(s): Scott Endo and Douglas Will

OBJECTIVE:

This demonstration was scheduled to allow National Park Service Forest Rangers to assess the TOV surveillance capability in observing illegal drug/explosives manufacturing and smuggling activities during both day and night conditions. Surveillance tests were conducted while detecting and observing movements of various suspect vehicles at different ranges.

APPROACH:

Provided a description of the demonstration, attendee observations/reactions, and problems/resolutions.

LESSONS LEARNED:

Proper battery recharge could not be maintained during the extended deployment of the TOV, resulting in the batteries being seriously degraded by excessive discharge. Since the project's beginning, the generator set (or Genset) has not been reliable. The AN/TAS-4 FLIR remote focus function does not operate properly. The control unit made by Kollsmann has a basic problem that has never been corrected by the manufacturer. The communications drawer in the operator's control rack still has a feedback problem with the intercom/field phone which essentially renders radio operation of the entire voice communications system useless. Modifications to solve this problem will probably require less than 45 man hours of labor. The video overlay readouts on the operator control station CRTs became intermittent and then failed altogether. Rather than a complete failure of the overlay board, we suspect it may only be a problem with the control of the character generator. The cable rewinding equipment is showing signs of wear. Replacement of the teflon pads along the winding path are urgently needed. The winding mechanism requires extensive cleaning as a result of the blowing sand and mud during field operation. The mobility head requires TOV's engine RPM to be elevated for proper operation. This eliminates overshoot in both the pan and tilt mode. This problem of overshoot, previously thought to be a calibration fault with the Polhemus, may in fact be due to not enough hydraulic pressure. The Navigator unit (Magnavox) was not used for this or any other demo as it has lost its ability to acquire a satellite.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Teleoperated Vehicle (TOV) After Action Report, 23 April 1991

Author(s): A. N. Pratt

OBJECTIVE:

To present the results of testing performed at Twenty-Nine Palms and Salton Sea, California.

APPROACH:

Discussion on beneficial changes needed in future models of the TOV.

LESSONS LEARNED:

BLT 1/9 enjoyed the opportunity to work with the Teleoperated Vehicle (TOV) during CAX 4-91 at MCAGCC Twenty Nine Palms, CA and at our 1/9 Special Operations Capable package at Salton Sea Naval Weapons Testing Center, CA. During both exercises, the battalion utilized the TOV as it would under actual conditions. We were pleased with the vehicle's performance. The TOV held up and operated well on rough terrain and during sandstorms. Recommend the following changes to the TOV: 1) zoom on camera greater than 10:1 to increase stand-off range; 2) SIMRAD in addition to the FLIR for increased night vision capability; 3) have a directional audio antenna slaved into camera; 4) change the navigation system to a GPS based system that would allow the user access to the navigator's screen in addition to the position screens; 5) a smaller laser range finder (such as the AN/GVS-5) slaved to the camera which is more eye safe and has a smaller profile. We still need a MULE for designating air targets; 6) radar beacon (RABFAC) and radar reflector for close air support; and 7) a radio with a large high gain antenna mount so vehicle can be used as a retransmission site.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Twenty-Nine Palms and Salton Sea, California, 3 May 1991

Author(s): Ray Zenick and Del Haddock

OBJECTIVE:

To present the results of testing performed at Twenty-Nine Palms and Salton Sea, California.

APPROACH:

This field report will cover two separate joint operations of the TOV and BLT 1-9 Marines. The first operation was an invitation to participate with the 1-9 during their pre CAX and CAX during January 1991. The second was a series of live fire assaults on a now defunct government facility on the edge of the Salton Sea in south east California. This second operation or series of operations, was either land based assaults or assaults by boat on land based targets.

LESSONS LEARNED:

Nelles Griot goniometers, which serve as adjustable camera mount interface, did not hold in both Pan and Roll, although locked securely. It was noted that the locking screws were still very tight. However, the assembly had slipped during the very rough road driving to the starting point of the CAX. The Mobility cameras were realigned in the field using a newly developed stereographic aligned technique in less than ten minutes. A very important message obtained from this CAX experience is that future robotic vehicles must be smaller in order that they may be airlifted to the next forward position. Video quality was intermittent and at times was very frustrating to several missions or portions thereof. The TOV system itself had nothing to do with the sometimes poor performance of the FLIR. These problems have plagued our FLIR units during the TOV program. Usually most video quality is a function of the scan converter, however this time it appeared to be the fault of the cryogenic cooler. For the distance between the operations and TOV, 200 to 400 mm optics is more realistic. 160 mm optics allows detail at 1 km for some vehicles in certain situations. It became clear during the CAX and at Salton Sea under typical missions that no detail of company level operations could be extracted other than their general movement and direction. It is obvious that TOV is not a workable piece of operational hardware. It embodies a concept and it should be used as an educational tool until STV is available.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title:	Input to Review Team, 30 May 1991
Author(s):	Walt Aviles

OBJECTIVE:

To provide comments on the STV review.

APPROACH:

Discussion of major concerns.

LESSONS LEARNED:

There is concern that detailed center of gravity and center of buoyancy calculations for remote vehicle systems have not been done. There is also concern about using the plastic connectors. According to Alan Umeda, these connectors were real problems in the early TOV EG&G systems. Alan has info on cheaper MIL-Style connectors which work very well. Need to determine if we want Auto Gain Control (AGC) on the fiber optic receivers. If we do not have AGC, we need to have a series of optical attenuators to allow shorter cable lengths to be used and will also need a couple of optical power meters as part of the Standard STV toolkit. We ended up installing an optical power meter in both the Control Station and Remote Vehicle in the earlier TOV days when we did not have AGC. Otherwise you will spend a lot of time making sure you are within the power range of the receiver. Switches on-board the remote vehicle really need to be re-vamped. The current switch configuration and types do not pay sufficient attention to safety and ergonomics. Switches controlling critical functions should be differentiated (color, shape, type) from switches controlling non-critical functions. Need to make sure that the human cannot be hurt when switching the remote vehicle system from "local" to "remote". Options are installing a separate timing circuit which guarantees a certain amount of time or putting the final master arming switch on the outside of the vehicle (still need a little time-out circuit though). There is concern about the mast system. First of all, RST was unable to give any overall stability and rigidity numbers (both static and in wind). The numbers should be for both the mast and the system as a whole when mounted on the platform. NOSC went through a very detailed design and analysis to get the rigidity and stability that we did. The pan action acceleration numbers (150 degrees per second per second) are too low. This would probably preclude HMD use. Current driving camera position is real bad for HMD use. Tilt axis of rotation is too low.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report - 21-24 May 91, 5 June 1991

Author(s): A. Y. Umeda

OBJECTIVE:

This memorandum summarizes A. Y. Umeda's trip to Robotic Systems Technology (RST). The objective was to participate in the technical review of RST's Surrogate Teleoperated Vehicle designs.

APPROACH:

Discussion of questions addressed to RST and the corresponding answers rece:ved.

LESSONS LEARNED:

The following issues are primary areas of concern: 1) lack of an emergency abort philosophy, 2) lack of a design concept for the OCU, and 3) optimistic delivery schedule with minimal testing prior to delivery. The STV has the following features: Dimensions - 108"(L) x 50"(W) x 52"(H) (height is to the top of the mast); Drive Controls - steering wheel (instead of handlebar), brake throttle (foot operated); Gross weight of system - nearly 2000 lbs; Speed - 0-20 mph (low), 0-38 mph (high) on level ground; Mast - 18"-108" from vehicle mount, 34" off ground, 220 lbs; Turret - 31"(W) x 36"(H). The brake has a position control loop with pressure feedback to improve operator control.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report - STV Design Review 5/23/91, 7 June 1991

Author(s): Stephen Martin

OBJECTIVE:

To present the results of the STV design review held on 23 May 1991.

APPROACH:

Discussion on areas of concern found during the review.

LESSONS LEARNED:

There is concern about details of the video and stereoaudio analog modulation filtering. Details of these filters were unknown to RST. The concern is that the video is low-pass filtered at 5.5 MHz and the audio is high-pass filtered at 6.0 MHz (modulated at a center frequency of 6.8 MHz). This is a very limited guard band and may result in the corupting of audio quality by video. From TOV experience it is not a good idea to require field insertion of attenuators to keep the optical signal within the receiver's dynamic range for various length F.O. cables. A robust and proper design and setup should make field attenuators unnecesary. The OCU to vehicle voice communication channel should have a low-pass filter (Anti-alias) prior to analog-to-digital conversion at the OCU. For human factors reasons, the master "local/remote/off" switch should be different from the others. Possible a switch panel cover to prevent operators from inadvertently activating an improper function while direct driving. Overall System Safety/Hazard Analysis should be treated as a separate review. It is not formally addressed as a topic in this review, but it had been discussed at various times. At 2400 Baud command link the turret update lag appears to be around 100 ms. This may pose a real problem for turret slewing during high speed driving, especially if head coupled vision is used. There is concern over the use of the commercial black plastic connector, especially in terms of water-tight integrity. Numbers of connectors also appears excessive which may cause access problems as well as potential decrease in reliability. Very little detail was provided (other than a drawing) concerning the camera alignment design, but it is suggested that they only need to align 4 DOF for a stereo pair (pitch one, roll one, and rotate both). Integrity of their alignments w.r.t. shock and vibration is uncertain. This is a serious safety consideration for the laser designator as their design does not have a camera viewing that scene except via a boresight aligned sensor.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: STV RST Program Review, 23 May 1991, 10 June 1991

Author(s): M. Solorzano

OBJECTIVE:

To address points of interest at the review.

APPROACH:

Discussed the scissors lift design, vehicle stability, target tracking, and the fiber optic link.

LESSONS LEARNED:

The fully elevated lift will present a significant wind load generating many tens of pounds of side loading. With a 9 foot torque arm on the vehicle, what will this do to image and targeting abilities? The center of gravity of the vehicle, both in lateral position as the mast elevates, and in the sagital plane, vary significantly. As the vehicle attitude varies, the vehicle stability will vary radically even before a tip over condition is achieved. This needs further study. The motion control schema does not appear entirely thought out. The type of motion control (rate vs position), and differing control ranges needed for precise distant target tracking versus rapid teleoperator tracking has not been addressed. The reliability and precision of the motion drive packages for the RSTA structure is no longer in question. These people did know the limits of what they are using. However, being unaware of high speed and high acceleration requirements of close range targeting or teleoperator head motions, they adopted a very low performance torque and acceleration capability. At the close of the day, Kevin Bonner came to realize that if he attempted to approach the minimal accelerations needed by high speed teleoperation, he would likely see motor failures. The most common shortcoming of the TOV vehicle was the repeated failures for various reasons, of the fiber-optic link. Primary among these was the integrity of the actual f-o connection. While the radio frequency control link seems to be designed to be the primary scheme, the f-o must be reliable to be usable.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Tactical Unmanned Ground Vehicle (TUGV) Trade-Off Analysis (TOA), October 1991

Author(s): Albert J. Nahas

OBJECTIVE:

To provide a Trade-Off Analysis (TOA) for the Tactical Unmanned Ground Vehicle (TUGV) to be used in the development of a Operational Requirements Document (ORD) for the TUGV, which will be a joint ORD with the U.S. Marine Corps.

APPROACH:

Description and justification for TUGV. Discussion concerning TUGV missions, TUGV influencing factors, analysis of system trade-offs, and TUGV preferred capabilities

LESSONS LEARNED:

TUGV system should be low cost and use off-the-shelf, reliable technology. The most important operational capability to support RISTA roles is mobility (operational range of 10 km). Low cost electro-optics, included a color television camera, are preferred. It is assumed that the TUGV will be able to survey threats at close range. A mast with a deployed height of 2 meters above the vehicle top and a deploying time of 1 minute is preferred. Capable of conducting NBC monitoring and reporting.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Interim BTA Input, 15 November 1991

Author(s): B. C. Caskey

OBJECTIVE:

To present Sandia's recommendations for the Interim BTA based on their experiences working with both the technologies and the users.

APPROACH:

Discussed of recommendations concerning TUGV overall system cost, MBU cost, OCU cost, communication systems, mission modules, and system integration.

LESSONS LEARNED:

TUGV chassis should be small, light, and preferably cost less than $10K. MBU electronics (including packaging and cabling) should be about $10K. Onboard TUGV navigation equipment should be approximately $5K. For the driving camera, recommend a single color CCD camera with a fixed 40-45 degree field-of-view lens (if this camera is to be used for RSTA, attach a zoom lens) mounted on a pan/tilt mechanism costing around $10K. The mast is considered as part of the mission module. Meeting the low cost goal requires that we do not try to build another M1 tank or HMMWV, but build a simple, expendable MBU that does not meet all mil-specs, is composed of largely NDI parts, and whose mission success probability is not 100%. Some key MBU cost drivers are speed, terrain, and payload requirements. Recommend using the smallest, lightest, least payload that will perform most (but not all) proposed mission profiles. Requiring an extra 250 lb capacity for a human may impose a cost penalty that can not be afforded. Fiber-optic systems have a high probability of being severed and are too costly ($1.50/meter) for an expendable system. Solutions to the communication system problem may involve an aerial asset (UAV or balloon), TUGV networking, and/or compression technology. Cost of on-board communication equipment must be below $15K. Handlebar controls are preferred when the operator is sitting, standing, or lying down. Stereo vision enhances identifying obstacles (particularly dropoffs). Adding weapons forces one to design considerable fail-safe features and to provide for the additional shock, vibration, and blast effects. Self-protection weapons are at odds with the notion of expendability.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Best Technical Approach, Interim Study, Unmanned Ground Vehicle, December 1991

Author(s): United States Army Missile Command, Research, Development, & Engineering Center

OBJECTIVE:

To provide the current status on the activities involved in support of the Unmanned Ground Vehicle (UGV) system design.

APPROACH:

Provide a summary of the preceding documents of the Concept Formulation Process (CFP) with respect to their applicability to each subsystem of the UGV. Discussion of progress made in evaluating each subsystem including issues, problems, recommendations, and supporting rational. A system integration outline is provided to establish guidelines for the final system design along with a baseline software system designed for future system growth.

LESSONS LEARNED:

System integration is a major task in the UGV design. The final Best Technical Approach (BTA) should include detailed cost examinations, system integration considerations, survivability/operational assessments, manprint, training inputs, personnel requirements, risk assessments (per component), and formulation of final briefings.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report, RISC Conference & COEE, 10 March 1992

Author(s): Leon Joly

OBJECTIVE:

To attend RISC '92 Conference and to support the Concept of Employment Evaluation.

APPROACH:

Supported the Concept of Employment Evaluation by performing the following activities: 1) observed indoctrination and hands-on familiarization training of the operators of the STV system, 2) assisted with the set-up and tear-down of the OCU, monitor, antennas, and cabling for the operator training, 3) assisted with the unloading of eight STVs, Fiber Optic Retrieval system, crane, and miscellaneous support equipment, 4) assisted RST with the final preparations on delivered STVs and maintenance of STVs already undergoing evaluation, 5) assisted NOSC with the tear-down and set-up of fiber optic cable on spools and with the removal and installation of fiber boxes, 6) followed the Unmanned Ground Vehicle around the course in an attempt to avoid property damage to the STV or it's surroundings, and 7) assisted with maintenance of the course used for training in the vicinity of Bldg 308.

LESSONS LEARNED:

STV has a relatively high center of gravity for it's narrow wheelbase and lists slightly to one side. The lack of peripheral vision was a major contributor in the operators becoming disoriented, cutting corners too sharply, running into things with the side of the vehicle, getting caught in places they had no business, and turning over the STVs. UGVs will probably have a requirement to communicate through one another. There will probably be a requirement for communications with the Tactical Operations Center which could involve the MBU. This isn't being considered. Either the Infantry School's appetite for a $500K to $1M system needs to be brought in line with their $50K to $150K budget or their budget needs to be increased to match their appetite. Otherwise, the programmatic risk associated with undertaking the EMD Program is unacceptably "high". The "user" needs to be discouraged from requiring things like the 15 lb OCU and a Dick Tracy TV wrist watch/radio during the 24-36 month EMD Program. The 15 lb OCU sets a dangerous precedent by implying that the UGV system can be carried by two soldiers.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report, Tactical Unmanned Ground Vehicle - CALEB Concept of Employment Evaluation Exercise, 24 March 1992

Author(s): Powell Johnson

OBJECTIVE:

To provide information concerning the Tactical Unmanned Ground Vehicle (TUGV) - Caleb concept of employment evaluation exercise (COEE) held at Fort Hunter Liggett, CA from 24 Feb - 14 Mar 92.

APPROACH:

Conducted practical exercises based on tactics and techniques from approved employment manuals and made modifications to these manuals to write the instructions that a soldier would receive, including a new standing operating procedure (SOP) that delineated each step a soldier or marine must make to use a UGV. In addition, daily discussion sessions were held between the participants and observers to review some of the positive and negative aspects discovered when using the STV in a realistic environment. These sessions were further characterized by technical discussion on how to make improvements in future unmanned systems.

LESSONS LEARNED:

The COEE successfully met each of the four major goals shown at TAB A, using a surrogate teleoperated vehicle (STV). The exercise afforded each of the participating schools and services with a realistic environment for experimenting with an STV and confirmed the need for continued evolution of teleoperation concepts to remove the soldier from very hazardous or high risk battlefield environments. Technical problems pertaining to the STVs and recorded by the CSTA data collectors, were comprised of approximately 150 technical incident reports (TIRs) describing equipment failures such as: difficulty in shifting gears during teleoperation, overheating of the MBU during certain maneuvers, braking software malfunctions causing the brakes to overheat, and repeated control responsiveness problems. TIRs for the OCU included failures such as: battery power loss, lack of icon displays on the control panel to cue the operator, and lack of vehicle operational data being displayed. The three primary areas of importance to participants in the COEE were driving, sensor, and OCU requirements which are shown at TAB D.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle Best Technical Approach, Progress Review Meeting Summary, 25 March 1992

Author(s): Dr. James Baumann and Larry W. Brantley

OBJECTIVE:

To provide a summary of information, issues, and recommendations discussed at the Best Technical Approach (BTA) meeting.

APPROACH:

Provide a bound report including a summary sheet and viewgraph materials discussed during the meeting.

LESSONS LEARNED:

Key issues are: uncertainty of the system requirements, definition of RISTA mission profiles, manned vs unmanned operation, use of MIL STD components, and the degree of militarization.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle, Workshop VI, 7-9 April 1992

Author(s): DARPA

OBJECTIVE:

To present the systems integration approach, review the related technology R&D programs, review the results of the preliminary sensor selection tradeoff matrices, discuss the MMC RSTA development approach, and evaluate the potential use of data compression for remote control.

APPROACH:

Discussion of: the program overview for the Surrogate Semiautonomous Vehicle (SSV) integration program; the SSV Demo Definition; SSV operational vs developmental needs; system analyses, trades, designs, issues; SSV system baseline; SSV RISTA definition; UGV stereo at SRI; the University of Michigan; Carnegie Mellon University; integrated perception and planning system; tactical planning for control of unmanned ground vehicles; Harry Diamond Laboratories; automatic target recognition at NVEOD; model-based target recognition techniques; model based ATR: algorithms based on reduced target models, learning and probing; CECOM packet radio; automatic target recognition research at Wright Labs with respect to un-manned ground vehicle RSTA technology requirements.

LESSONS LEARNED:

Demonstrations of UGV system technologies will be as follows:

Demo A, Denver, May 1993 - Basic System Capabilities
Demo B, Huntsville, May 1994 - Robust Autonomous Capabilities
Demo C, Huntsville, November 1994 - Multivehicle Cooperative Control
Demo II, Ft. Hood, May 1995 - Movement to Contact, Screening and Delaying
Extended Technology Demo (Optional), November 1995 - UAV Enhanced Mission Map

Various comparison tables showing possible candidates for communication links (system analyses, trades, designs, issues) and navigation sensors (system analyses, trades, designs, issues). RISTA on the move is not possible. Proposed RSTA, target designation package (SSV RSTA Definition), ATA candidates, and ATR candidates.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle Best Technical Approach, Progress Review Meeting Summary, 15 April 1992

Author(s): Dr. James Baumann and Larry W. Brantley

OBJECTIVE:

To provide a summary of information, issues, and recommendations discussed at the Best Technical Approach (BTA) meeting.

APPROACH:

Provide a bound report including a summary sheet and viewgraph materials discussed during the meeting.

LESSONS LEARNED:

BTA Team needs to complete developers perception of operational concept and requirements and obtain feedback from the combat developer prior to generating the final UGV configuration. Team members should be developing a candidate configuration for their area (based on assumed requirements) along with cost and risk.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report, TeleOperated Vehicle Program Briefings, 25 April 1992

Author(s): Leon Joly

OBJECTIVE:

To document NCCOSC technology base experience relating to Unmanned Ground Vehicles (UGVs) in areas of vehicles, driving and RISTA sensors, displays, the TOV, and the STV.

APPROACH:

Attended the following tours and meetings: Manipulator Performance Lab Tour, TeleOperation Performance (TOPS) Lab Tour, Fast Attack Vehicle & HMMWV/TOV Area Tour, Ground Air Teleoperated Robotic System (GATERS), Teleoperated Vehicle (TOV) Command Link, GATERS/TOV Program, TOV System Development, TOV System Requirements, Head Mounted Display Technology, TOV/STV Driving/RISTA Sensors/Masts/Servos, Mono vs. Stereo/Vehicle vs Gravity Reference Demo, TOV/STV Operator Control Unit Displays and Controls, TOV/STV Power, STV Overview, STV Turret/Electronics, STV Operators Control Unit, STV Fiber, STV: Recommended Changes for Improvement, and Human Factors for Teleoperated Vehicles.

LESSONS LEARNED:

Vehicle recommendation is a function of on-road/fast/chase retreating armor missions (HMMWV) vs. off-road/complex terrain missions (ATV). The STV is an ATV candidate, but needs re-engineering. NCCOSC feels that there needs to be some mechanism for performing mission planning, coordination, and command and control with higher echelons. Driving cameras should have a wide field-of-view, stereo, color, peripheral vision, and high resolution (in that order) for driving in off-road complex terrain. The cameras should see the the front corners of the vehicle and have an additional gimbal to provide gravity reference. The driving cameras should be separate from the RISTA cameras, but not necessarily on separate mounts. Mast height should be at most twice the height of the vehicle and acoustic sensors are mandatory. Color cameras are preferred, but not necessary for RISTA. RISTA on-the-move should not be attempted since stabilization would be required at additional cost. A better approach is to perform a RISTA mission, then move quickly to a new RISTA location.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Trip Report, Demo I Robotics Demonstration, 14 May 1992

Author(s): Suzy Young

OBJECTIVE:

To participate in the Demo I Robotics Demonstration.

APPROACH:

Demonstration of the capabilities and potential of robotics technology to the military user community and to other military and civilian tactical warfare planners. Through live hands-on field operations, along with briefings, static displays and video presentations, Demo I will illustrate technology developments relevant to unmanned ground vehicles in the following areas: navigation, control, man-machine interface, effector (mission packages), communications, and robotic vehicular platforms.

LESSONS LEARNED:

The ATA package consisted of a visible-light CCD camera, infrared sensor, and laser rangefinder. Combined with this system was the MILES, Multiple Integrated Laser Engagement System, to visibly determine target engagement. Retro-traverse was performed using the MAPS (Modular Azimuth Positioning System) inertial navigation unit. Vehicle #6 demonstrated the CARD system (which allowed the operator to plan a three dimensional path for the vehicle to traverse in an autonomous mode) operating via SINCGARS, a stereo vision technique employing electronically shuttered glasses, and an automatic stop function based on navigation (VNAS) error. The autonomy utilized an image understanding algorithm to detect road edges and compute low level controls to operate the vehicle. A MTI (Moving Target Indicator) processor was demonstrated. This sensor was a Hitachi daylight, 10:1 zoom, color camera mounted on a 350 degrees azimuth, 60 degrees per second rotating, 60 degrees, (+/-), elevation pan/tilt platform. DSTI demonstrated a system developed for UGV JPO/MICOM on a feedback limited control system (FELICS). Transmitting a video frame rate restricted to less than one frame per second, local driving is augmented with supervisory driving controls by enabling the operator to plan the path by navigating waypoints within the given scene. Low data rate driving was demonstrated by using the following techniques: pyramidal decomposition, foveation, and image quality versus frame rate trade offs.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle Best Technical Approach, Progress Review Meeting Summary, 19 May 1992

Author(s): Dr. James Baumann and Larry W. Brantley

OBJECTIVE:

To provide a summary of information, issues, and recommendations discussed at the Best Technical Approach (BTA) meeting.

APPROACH:

Provide a bound report including a summary sheet and viewgraph materials discussed during the meeting.

LESSONS LEARNED:

Detection of tracked, rotary wing, and fixed wing vehicles is possible with currently available signal processing techniques, but identification will require expensive advanced signal processing techniques and is not feasible for the initial UGV system. Chemical detection capabilities will not be a problem in the UGV design, however, providing NB capabilities on the initial UGV system may be a cost driver. The final BTA report will be broken into the following major sections: 1) Executive Summary, 2) Introduction, 3) Concept and Requirements, 4) Mobile Base Unit (MBU), 5) Payload, 6) Communications Datalink, 7) Operator Control Unit (OCU), and 8) System Integration. Current recommendations for the initial UGV system include 3-D, color video imagery for driving; 2-D, black and white video imagery for RISTA; the use of Mil-STD parts; day/night driving (45-60 degree FOV) and targeting cameras; a rangefinder; and a chemical detection capability. Preliminary findings indicate that the datalink will be RF not fiber optics. The identification requirement in the ORD dated 15 May will be a system cost driver unless this requirement is changed to a detection requirement. Recommend that 1) the distance for identification be shortened or 2) accept the increase in cost associated with the sophisticated equipment necessary to meet the current requirement. ANTAS 4, Hughes Heavy and Medium Thermal Weapon Sight, and the French-made Sofidor are candidates for the night targeting sensor. Image intensifiers have been examined and it has been found that they do not provide sufficient resolution, field-of-view, or standard video imagery. The laser designator capability should be made modular due to mission objectives and associated costs.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Unmanned Ground Vehicle Best Technical Approach, Progress Review Meeting Summary, 10 June 1992

Author(s): Dr. James Baumann and Larry W. Brantley

OBJECTIVE:

To provide a summary of information, issues, and recommendations discussed at the Best Technical Approach (BTA) meeting.

APPROACH:

Provide a bound report including a summary sheet and viewgraph materials discussed during the meeting.

LESSONS LEARNED:

A refined description of the BTA process was presented as follows: 1) conduct a literature review to establish the state-of-technology, 2) develop an operational requirement summary, 3) translate operational requirements into system requirements, 4) decompose system requirements into subsystem requirements, 5) identify critical subsystem requirements, 6) identify alternative subsystem solutions, 7) analyze system integration/software issues, and 10) recommend the best technical approach. Currently, the ORD contains the most current description of the operational capabilities desired by the user, and therefore, the BTA team will be most concerned with meeting the requirements laid down in the ORD. VNAS navigation unit has been eliminated as a navigation unit candidate due to high cost ($40K). Typically night sensors (i.e. FLIR) can detect targets more easily than TV sensors, but have reduced resolution which makes target recognition and identification more difficult. On the other hand, TV sensors can recognize and identify targets more easily than night sensors, but have difficulty detecting targets. The teleoperator will perform the identification of friend or foe. Approximately 100 references discuss critical aspects of the UGV design effort and will effect the BTA recommendations. The Hughes Thermal Weapon Sight is recommended for the night sensor on the initial UGV. Driving and RISTA cameras need to be separate for the following reasons: 1) system should be modular (could operate vehicle without performing a RISTA mission), 2) could have two operators -- one for driving, one for RISTA, 3) allows for gravity referencing the driving cameras which you do not want to do for the RISTA cameras, and 4) simplifies maintenance and weight.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Definitions of Generic Terms

Author(s): T. B. Sheridan

OBJECTIVE:

To provide definitions for terms used in describing robotic systems.

APPROACH:

Present a list of terms and their associated definitions.

LESSONS LEARNED:

The term supervisory control is derived from the close analogy between the supervisor's interaction with subordinate human staff members in a human organization and a person's interaction with "intelligent" automated subsystems. In the strictest sense, the term supervisory control means that one or more human operators are continually programming and receiving information from a computer that itself closes an autonomous control loop through artificial effectors and sensors to the task environment. In a less strict sense, supervisory control means that one or more human operators are continually programming and receiving information from a computer that interconnects through artificial effectors and sensors to the task environment. Telepresence means the operator receives sufficient information about the teleoperator and task environment, displayed in a sufficiently natural way, that he feels himself to be physically present at the remote site. This can be a matter of degree. Naturally an operator upon reflection knows where he really is. Nevertheless the illusion of telepresence can be compelling provided the proper technology is used. A more restrictive definition of telepresence requires further that the teleoperator's dexterity match that of the bare-handed human operator. In spite of the considerable current popularity of the term, the usefulness of imparting telepresence is obscure at the present time. Virtual presence, or synonymously a virtual environment or virtual reality, is experienced by a person when sensory information generated only by a computer compels a feeling of being present in an environment other than the one he is actually in. With sufficiently good technology a person would not be able to discriminate between actual presence, telepresence, and virtual presence.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Draft Required Operational Capability (ROC) for a Unmanned Ground Vehicle (UGV) System

Author(s): U. S. Army Infantry School

OBJECTIVE:

To provide a description of the required operational capabilities for the UGV.

APPROACH:

Presented a discussion on the need, threat and operational deficiency, operational and organizational concepts, essential characteristics, inter/intraoperability and standardization requirements, related efforts, technical feasibility and energy/environmental impacts, life cycle cost forecast/estimate, manpower requirements, training requirements, and amphibious/strategic lift impact.

LESSONS LEARNED:

Essential characteristics: 1) The remote platform will display mobility at least comparable to a similarly loaded HMMWV; 2) In order to provide the operator with the sense of remote presence, the onboard UGV video system will provide a stereoscopic image to the operator at the control station. Camera movement will be remotely controlled by the operator's head movements; 3) The acoustical sensor must allow normal human sound localization capabilities at the remote site; 4) Detect, acquire, and identify targets with a capability comparable to that provided by the A/N-TAS 4B (TOW II sight); 5) Designate a target using a designator such as the modular universal laser equipment (MULE) or its replacement. The designator will not be an integral part of the module but will be supplied by the supporting unit; 6) From the control station; safely arm/operate a machine gun and apply immediate action to reduce stoppages; 7) Conduct UHF ground-to-air communications; 8) Employ the current radar beacon forward air controller (RABFAC) from the remote platform site. The radar beacon is not required to be an integral part of the module but will be supplied by the supported unit; 9) Provide secure, non-jammable communication when the remote platform is beyond the line-of-sight of the control station; and 10) Determine the range to any target up to at least 10 km distance with an accuracy to +/- 10 meters.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Introduction to the Marine Corps GATERS Program (Ground-Air TeleRobotic Systems)

Author(s): Department of the Navy, United States Marine Corps and Naval Ocean Systems Center

OBJECTIVE:

To present a description of the GATERS program.

APPROACH:

Discussion on program initiation, program management, TOV/AROD Acquisition, related activities, teleoperated vehicle system technical characteristics, advanced teleoperator technology, AROD technical characteristics, transition risk assessment, and major program hurdles.

LESSONS LEARNED:

Robot - An adaptive system having sensors and actuators for mobility and/or manipulation that needs no human operator. It can be preprogrammed to accomplish predefined missions or in more advanced systems is capable of performing task after making limited decisions based on previous experiences or onboard "knowledge"; Teleoperator - A system having sensors and actuators for mobility and/or manipulation, controlled by a human (in real time), thus enabling the operator to extend his sensory-motor functions to remote or hazardous environment. In teleoperation a symbiotic (mutually beneficial) relationship exists between man and the machine. Man needs the machine's strength and resistance to hostile environments and the machine depends on man's brain and dexterity; Remote Presence - The technique of integrating the operator of a teleoperator system into the display/controller so that the man-machine interface approaches transparency and provides a realistic sensation of being at the remote site; Remote Control - A general, descriptive term referring to a closed, man-in-the-loop control system which does not require direct feedback from the remotely deployed unit. Typically used in reference to models where loop closure is accomplished by visual observation/correlation. Teleoperated Vehicle System Technical Characteristics: 2500 lbs (1135 kg) gross weight, 1000 lbs (455 kg) payload, internal fit in CH46, MV22 "OSPREY", 80 km/hr on road, 35 km/hr off road, 24 hr endurance, 20 km radius, 4 hr duty/half hour recharge, day/night, binaural hearing, navigation in military grid coordinates, fiber optic command control data link (primary), RF (backup), -30° to +65° C, rain, snow, salt spray, ice snow, mud, sand, all soil types.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: Sandia National Laboratories Robotic Vehicle Controllers

Author(s): Sandia National Laboratories

OBJECTIVE:

Sandia's OCUs range in size from a small single-man-portable controller to a controller consisting of three 19 inch equipment racks. Four of these controllers are summarized here.

APPROACH:

Discussion of the Remote Security Station (RSS) Controller, DOE/OSS Robotic Security Vehicle OCU, Dixie Desk and Micro Controller.

LESSONS LEARNED:

The RSS system has an Acoustic Detection Tracking and Classification System (ADTACS) which uses signals from three equally spaced microphones to detect acoustic sources, determine their bearing, and classify the source. The RSS also has a Video Motion Detection (VMD) system which processes video signals received from the Telemanaged Mobile Security Station or Man-Portable Security Station and produces an alarm output in response to a target moving against a fixed background. Although a joystick driving interface provides adequate control of the vehicle, experience with other driving stations has shown a steering wheel and pedals to be easier to use. It is our opinion that greater driving speeds can be achieved and less operator fatigue occurs with that type of system. After two years of using the Desk Controller, many people have controlled Dixie in sundry conditions. In general, the response and performance of these drivers indicates that the major objective of providing an easily mastered OCU has been realized. The major goal of the Micro Controller (MC) was to reduce the size of the Desk Controller (DC) without sacrificing the simple interface or losing capability. This goal has also been realized. This OCU is 1/6 the size of the Desk Controller and only 1/2 the weight. The capabilities are identical to the DC. One area of compromise however is the joystick. The MC is so small that pedals can not be used. Consequently, additional training time is required for operators to acquire fine control of the steering/brake/throttle joystick. Some input devices are necessary for rapid activation and they should be implemented with dedicated switches or buttons, but others that are less frequently used can be implemented by the use of input devices whose function changes under software control, such as a touchscreen or a keypad.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

REFERENCE PAPER SUMMARY

REFERENCE:

Title: System Specification for the Teleoperated Vehicle (TOV)

Author(s): SEACO/SAIC

OBJECTIVE:

This document provides the draft specifications for the Teleoperated Vehicle (TOV) prototype system. It includes the technical and mission requirements for functional areas, design constraints, and interfaces areas. This specification will be used to establish the general nature of the system that is to be further defined and finalized during the Demonstration and Validation phase of this program, scheduled to commence in FY-90.

APPROACH:

Discussion of applicable documents, system requirements, quality assurance provisions, and intended use.

LESSONS LEARNED:

The TOV system is composed of: three remote vehicles, various mission modules, a 10 kw trailer-mounted generator set, a control van containing three operator control stations and a section leader station. Fiber-optic cable is utilized as the data link between the control van and the remote vehicles. The cable must freely pay out from the moving TOV at a rate of 100 km per hour without causing entanglement with or restricting the maneuverability of the vehicle in any way. Replacement of fiber-optic cable spools must be easily accomplished within 15 minutes by organizational level personnel using standard organizational level tools. A practical means of recovering and repairing expended fiber-optic cable for re-use is required The cable recovery system shall be capable of recovering fiber-optic cable on one spool at the rate of 15 kilometers per hour. The system shall be capable of being powered by the HMMWV vehicle, and be simple in design for field maintainability. The system shall be vehicle mountable and require no more than two Marines to operate it. The total gross weight for a fully configured TOV (with mission module, fiber-optic cable, ammunition, etc.) will not exceed 7,500 lbs (3,402 kg). The TOW 2 weapons system is an easily transportable, heavy anti-tank weapon capable of attacking and defeating armored vehicles and other land targets such as field fortification and concrete bunkers. The bare MK19 weighs 75.6 lbs, has a blow-back action with a cyclical rate of fire of 325 to 375 rounds/minute, and is fed from 20-round or 50-round ammunition belts. The M2 machine gun is an automatic recoil operated alternate-feed, link-belt fed, air-cooled, crew-operated weapon.

APPLICABLE TO CURRENT UGV DESIGN EFFORT: Yes

APPENDIX A

UGV CHRONOLOGICAL REFERENCE LIST

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